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TECHNICAL REPORT
67-23-CM

LIGHTWEIGHT INSULATED FOOTWEAR

by

Robert W. Pooley
Leighton E. Fisher

U. S. Rubber Co.
Mishawaka, Indiana

and

Alexander D. Shaw, III
Conrad S. Rohs

U. S. Rubber Co.
Naugatuck, Connecticut

Contract No. DA19-129-AMC-690(N)

September 1966

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Clothing and Organic Materials Division
C&OM-26

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Project Reference:
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Series: C&OM-26

Clothing and Organic Materials Division
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

FOREWORD

The standard black insulated Army boots developed for cold-wet conditions weigh approximately 40 ounces per boot. Studies indicate that, in reference to energy consumption, 1 ounce carried on the foot is equivalent in weight to 6 ounces carried on the back (30-pound equivalent).

In view of this, development of new lightweight materials for insulated footwear is essential. The boots should be in the weight range of 15 to 18 ounces per boot and offer environmental protection at temperatures as low as $-20^{\circ}F$. The U. S. Army Natick Laboratories determined to meet this objective by taking advantage of advances made in materials technology and through the development of new design criteria.

Under the supervision and guidance of Project Officer Joseph E. Assaf, U. S. Army Natick Laboratories, the materials and fabrications studies described in this report were performed by the U. S. Rubber Company through Contract No. DA19-129-AMC-690. Copper Foot studies were conducted at NLABS. A preliminary climatic chamber evaluation of materials assembled in boot form was performed and recorded by the Project Officer and appears as Appendix A of this report.

The Project Officer wishes to acknowledge the aid and guidance of Mr. Douglas Swain, Footwear Technologist, relative to design consideration, and of Dr. Herman Thies, Consultant. He also wishes to thank Dr. Ralph F. Goldman and Mr. John Breckenridge of the U. S. Army Research Institute of Environmental Medicine (ARIEM), a tenant activity at Natick for conducting the Copper Foot calorimeter studies and for their valued suggestions; and Mr. Edwin Zelezny and Mr. John Arbarchuk for assistance in the climatic chamber studies.

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ABSTRACT

In this study, a number of candidate materials were compounded, tested, and evaluated with an aim toward the development of a lightweight (15 oz. per boot), impermeable, (water absorption maximum weight 5%), insulated, (for service down to -20°) boot for periods of up to 2 hours of inactivity.

These materials included expanded elastomers and plastics, solid plastics, metals, fabrics, adhesives, and coating materials.

Design and fabrication studies were conducted to incorporate the most promising materials into a prototype boot, and to determine the insulating properties of the materials used singly and in combination with each other.

Based on the data obtained, prototype boots were assembled. An experimental pull-on type boot weighing 15½ ounces was worn by the Project Officer in the Climatic Test Chambers at the U. S. Natick Laboratories at -30°F. for a period of 2 hours.

These studies indicate the feasibility of producing lightweight insulated boots through materials research.

LIGHTWEIGHT INSULATED FOOTWEAR

INTRODUCTION

The work described in this report was performed by the U. S. Rubber Company toward the development of lightweight (15 oz. per boot) impermeable, (water absorption maximum weight 5%), insulated footwear (for service down to -20°F. for periods up to 2 hours of inactivity).

It was determined that to achieve a significant reduction in weight, it was necessary to make full use of advances made in materials technology since the development of the standard black insulated Army boot which was designed for cold-wet wear.

The development of new lightweight materials to be used as components or groups of components in fabricating lightweight, insulated footwear in the weight range of 15 to 18 ounces per boot is essential.

The results of research directed toward the development of new, lightweight insulated footwear incorporating the newest ideas in materials and construction become significant when related to the system projected to lighten the weight of clothing and equipment for the combat soldier (LINCLOE).

SECTION 1 - MATERIALS STUDIES

Original Candidate Selection

A. Outsoles

Two variations of each of the following:

1. Expanded EPDM (Royalene, ethylene-propylene terpolymer)
2. Expanded CR (Neoprene)
3. " NBR (Paracril(R), nitrile rubber)
4. " IIR (Butyl rubber)
5. " CSM (Hypalon(R))
6. " PVC/NBR (polyvinyl chloride/Paracril)
7. " Polyurethane
8. " Polyethylene

B. Midsoles/Insoles

The same as for outsoles.

C. Shank Supports

Two thicknesses of the following:

1. Stainless steel
2. Hard aluminum alloy
3. ABS (acrylonitrile-butadiene-styrene) plastic
4. Acetal plastic
5. Nylon plastic
6. Polycarbonate plastic

D. Reinforcements for Counters and Toe Caps

Two varieties of each of the following:

1. Semi-rigid expanded ABS
2. Rigid expanded ABS
3. Impregnated woven Nylon fabric
4. Impregnated woven polyester fabric
5. " " glass fabric
6. " non-woven Nylon fabric
7. " " " glass "

E. Reinforcement for Vamp

Two knit and two woven fabrics of the following:

1. Nylon
2. Polyester

F. Liner

Two weights and two weaves of the following fabrics:

1. Nylon
2. Polyester

G. Exterior Coating

Two compounds of each of the following:

1. Polyurethane
2. IIR, Butyl rubber
3. EPDM, Royalene
4. CSM, Hypalon
5. IM, Vistanex(R)

H. Insulation

The same candidates as for outsoles.

I. Auxiliary Components

To be selected from design considerations.

J. Adhesives

To be selected dependent upon the other successful candidates.

Sample Preparation

A. EPDM (Royalene) for Soles and Insulation

No development was necessary on these materials as they are in the process of being made commercially by the United States Rubber Company (hereafter referred to as USRC). They were made as shown in Table 1.

The Chelsea frame referred to here and throughout the report is a piece of metal normally 1/4-in. thick (other thicknesses are specified where used). It is preferably of steel though hard aluminum alloy may be used. The frame is square and a square hole of the desired dimensions is cut out of the center of the sheet of metal. The width of the metal surrounding the hole can vary but must always be wide enough to contain the pressures generated by the blowing agents.

Before sample preparation started, it was decided to press pre-cure all cellular materials. Experience has shown that this gives better water absorption resistance than processes that simultaneously expand and cure. All samples were cooled in the press before releasing pressure. All expansions were free in hot air.

B. CR Neoprene, Soles and Insulation

1. Series 1006

A and B were for outsoles, C and D for midsoles, and E and F were for insulation in this series. E and F had less filler and a less powerful curative system for softness and increased blow. The following cures were run on 1006:

FORMULA	PRE-CURE	EXPANSION	COMMENTS
1006A	Press 12'/280°F.	15'/340°F.	Did not expand
"	" 8'/280°F.	"	Slight expansion
"	" 6'/280°F.	"	Slight expansion
1006D	Hot Air 12'/280°F.	10'/340°F.	Rough, expansion OK
"	Press 3'/250°F.	10'/350°F.	" " "
1006E	Hot Air 12'/280°F.	20'/340°F.	" " "
"	Press 6'/250°F.	15'/340°F.	" " "

The hot air pre-cures which were tried to gain more expansion were made by milling to thickness, calendering to thickness, and cold pressing to thickness. It was obvious from the above that cure rate was not progressing properly with expansion. Though the toughness and set properties of 1006 were desirable, it was abandoned due to its processing problems.

2. Series 1015

Series 1015 with NA22 and diethyl thiourea was substituted for 1006. Mill mixing was substituted for Banbury mixing to insure good dispersion. The following variations were tried on 1015A:

VARIATION	PRESS PRE-CURE	EXPANSION	COMMENTS
None	20'/325°F.	30'/340°F.	Overcured. No expansion.
Diethyl Thiourea Omitted	20'/325°F.	10'/350°F.	" " "
0.5 Part MBTS Added	5'/280°F.	15'/325°F.	Undercured.
0.5 Part MBTS Added	10'/280°F.	15'/325°F.	Very coarse cells.

1015D was press pre-cured 20'/280^{o}F. and expanded 30'/325^{o}F. This also failed to expand due to overcure.

Again it was decided that the curative system was too time-temperature sensitive. It seemed probable that each formula of 1015 would require careful development of pre-cure and expansion times and temperatures for good samples just as with 1006. 1015 was then abandoned.

3. Series 1021

Series 1021 was substituted for 1015. Thionex$^{(R)}$, DOTG, and sulfur replaced NA22 and diethyl thiourea. 1021A press pre-cured 20'/280^{o}F. and expanded 20'/340^{o}F. showed some outgassing in expansion but were fair samples. 1021B was prepared with a press pre-cure of 18'/300^{o}F. and expansion of 15'/340^{o}F. This latter cure expansion gave good samples and the complete 1021 series was made with this cure-expansion.

A 1021A sample was left for 72 hours after having been press pre-cured 20'/300^{o}F. When it was then expanded, the amount of expansion was much less than on other samples. This indicates that 1021 compounds should be used within about 24 hours to avoid cure problems.

C. NBR Paracril, Soles and Insulation

1. Series 1007

Note in the mixing instructions of series 1007 that this compound should rest 8 hours before using. The following cure and expansion variations were made on 1007A:

PRESS PRE-CURE	EXPANSION	COMMENTS
20'/300^{o}F.	15'/340^{o}F.	Blisters.
20'/325^{o}F.	15'/340^{o}F.	Blisters worse than above.
2'/225^{o}F.	15'/340^{o}F.	Poor cure. Good expansion.
10'/300^{o}F.	15'/340^{o}F.	" " " "
15'/300^{o}F.	15'/340^{o}F.	Fair samples.

At this point 1007 was abandoned in favor of the greater processing latitude of 1016.

2. Series 1016

The first attempt with a press pre-cure of 25'/300^{o}F. and expansion of 15'/340^{o}F. gave good samples. This was

used for all of the series. Note that this is mill mixed and requires no stock resting time.

D. IIR Butyl, Soles and Insulation

Note in series 1013 that there are three groups of formulas. A and B were for outsoles; C and D were for midsoles; and E and F were for insulation. The following cure and expansion variations were made:

FORMULA	PRESS PRE-CURE	EXPANSION	COMMENT
1013A	20'/300°F.	20'/340°F.	CMF omitted. Undercured.
"	30'/300°F.	20'/340°F.	" " Fair sample.
"	5'/280°F.	20'/340°F.	Fair sample. More expansion than desired.
1013B	5'/280°F.	20'/340°F.	Fair sample.
"	7½'/280°F.	20'/340°F.	" "
1013C	5'/280°F.	20'/340°F.	" "
"	7½'/280°F.	20'/340°F.	" "
"	10'/280°F.	20'/340°F.	Surface cracked.
1013D	5'/280°F.	20'/340°F.	12 parts Celogen AZ(R). Surface cracked.
"	10'/280°F.	20'/340°F.	12 parts Celogen AZ. Surface cracked.
"	5'/280°F.	20'/340°F.	7 parts Celogen AZ. Fair sample.
1013E	7½'/280°F.	15'/340°F.	1 good sample but all others had surface cracks.
1013F	7½'/280°F.	15'/340°F.	Surface cracked so deeply that 1013F was abandoned.

Samples submitted for physical tests were as follows:

FORMULA	PRESS PRE-CURE	EXPANSION	COMMENT
1013A	5'/280°F.	20'/340°F.	8 parts of Celogen AZ.
1013B	7½'/280°F.	20'/340°F.	5 " " " "
1013C	7½'/280°F.	20'/340°F.	10 " " " "
1013D	7½'/280°F.	20'/340°F.	7 " " " "
1013E	7½'/280°F.	15'/340°F.	12 " " " "

It was concluded that about 7-1/2 lbs. per cu. ft. was the lowest density that could be produced so 1013F was not submitted for tests.

E. CSM Hypalon, Soles and Insulation

1. Series 1020

This blend of Hypalon 20 and 40 gave the best combination of expansion and processing properties. Vistanex was used to improve gas holding characteristics.

The Vistanex gave an uncured material that was tacky on the surface yet did not laminate well in the press pre-cure. The cure-expansion also was quite time-temperature sensitive as can be seen in the following:

FORMULA	PRESS PRE-CURE	EXPANSION	COMMENTS
1020A	20'/280°F.	15'/340°F.	Poor lamination. Very poor expansion.
"	20'/300°F.	"	Poor lamination. Very poor expansion.
"	20'/325°F.	"	Poor lamination. Very poor expansion.
"	20'/300°F.	"	2 parts stearic acid added. Poor lamination. Some expansion.
"	20'/300°F.	"	2 parts stearic acid and 20 parts litharge added. Poor lamination and expansion.

Series 1020 was abandoned at this point due to stickiness of the compound and cure-expansion problems.

2. Series 1031

Polyethylene was substituted for the Vistanex as a gas holder in this series and stearic acid was added to aid activation of the Celogen. The following variations were tried:

FORMULA	PRESS PRE-CURE	EXPANSION	COMMENTS
1031A	20'/300^{o}F.	20'/340^{o}F.	Delaminated, very poor expansion.
"	20'/325^{o}F.	"	Slab from mill so that there were no laminations. Very poor expansion. Defects looking like delaminations present.

3. Series 1032

Series 1032 had a completely different cure system from 1031 designed for less critical time-temperature dependency. The following cure-expansions were run:

FORMULA	PRESS PRE-CURE	EXPANSION	COMMENTS
1032A	20'/280^{o}F.	20'/340^{o}F.	Good samples.
"	Overcure	"	Internal blisters.
1032B	20'/280^{o}F.	"	" "
"	18'/280^{o}F.	"	Good samples.
1032C	"	"	" "
1032D	18'/280^{o}F.	"	Not cooled between Parts I and II in milling. Overcured.
"	"	"	Good samples.
1032E	"	"	" "
"	"	"	Uncured stock aged over weekend. Internal blisters.
1032F	"	"	A few internal blisters but otherwise good.

F. PVC/NBR (Polyvinyl Chloride/Acrylonitrile) Soles and Insulation

Series 1005 PVC/NBR formulas A and B are for soling and C and D for insulation.

1005A and B were first press pre-cured 30 min. @ 225°F. and then expanded 15 min. @ 300°F. These samples delaminated during expansion. A press pre-cure of 40 min. @ 303°F. with an expansion of 15 min. @ 340°F. without gaskets was unsuccessful.

The gaskets used are about Shore A 70 rubber 1/4" thick. Strips of proper length 1/2 - 1" wide are laid inside the Chelsea frame. Without a gasket some gas from the blowing agent is lost during the press pre-cure.

1005C and D were press pre-cured first 40 min. @ 303°F. These were overcured. A 20 min. @ 300°F. pre-cure did not laminate, indicating undercure. The successful samples were made with a 30 min. @ 300°F. press pre-cure and expansion of 15 min. @ 340°F.

G. Polyurethane for Soles Only

Expanded polyurethane for soles required no development as it (like the cellular Royalene) is also in the process of being manufactured commercially. Note that the midsole/insole formulation contains Nitrosan(R) blowing agent. This was necessary to achieve a 14 lb./cu. ft. density.

Liquid polyurethanes in preference to millable gums were chosen as raw material due to lower cost, the ease and advantage of liquid processing, and general excellent properties. The same reasoning applied to the choice for exterior coating.

H. Polyethylene, Soles and Insulation

Series 1023 was based on United States Rubber Company patent No. 3,098,832. Preparation and processing gave almost no difficulties. All press pre-cures were 20'/325°F. A and B were expanded 40'/310°F., but C, D, and E were expanded 20'/310°F. Calendering imperfections caused blisters on 2 samples. It was found advantageous to cross grain calendered sheets in the Chelsea frame and to place a flat board on the hot expanded samples to prevent curling.

Care must be taken to allow a 10-20% increase in volume during the press pre-cure.

I. Shank Supports

Stainless steel type 304 and aluminum alloy type 6061-T6 were chosen and ordered by the Divisional Laboratories Engineering Section. Kralastic(R) (ABS) sheet was furnished from the

USRC Chicago Plant. Acetal (Delrin(R)) sheets were purchased from Hyaline Plastics Corp. Nylon and polycarbonate (Lexan(R)) sheets were purchased from Cadillac Plastics Company.

J. Expanded Semi-Rigid ABS, Reinforcement for Counter and Toe Cap

It was found necessary to cross grain the calendered sheets of series 1035A in the Chelsea frame (1/8-in. deep frame used) in the press pre-cure. The following cure-expansion variations were made:

PRESS PRE-CURE	EXPANSION	COMMENTS
30'/300°F.	40'/300°F.	Very little expansion.
30'/325°F.	"	" " "
15'/300°F.	30'/340°F.	Good samples used for testing.

The difference in density noted between second and final screening tests was due to a defective expansion oven in the second screening material. This was true for both series 1035 and 1034.

K. Expanded Rigid ABS, Reinforcement for Counter and Toe Cap

It was necessary to cross grain the calendered sheets of series 1034A in the press pre-cure Chelsea frame (1/8-in. deep). Precure was 30'/300°F. and expansion 40'/300°F. No variations were found necessary.

L. Impregnated Fabrics, Reinforcement for Counter and Toe Cap

All fabrics used were obtained through our central purchasing office in New York. These fabrics were impregnated with both polyester and polyether polyurethanes. An 8 oz./sq. yd. weight was chosen to give strength and thickness. The impregnation was carried out as outlined below. The fabric was laid on a sheet of Crocker Hamilton's Stick Not 762 release paper. A second sheet of Stick Not 762 was used on top of the urethane and fabric. A urethane-MOCA mixture was poured on top of the fabric at one end. The top release paper held at the desired urethane-fabric thickness was then pushed across the fabric. This pushed and spread the urethane over and into the fabric. The urethane was allowed to cure at room temperature and the samples were stripped from the paper.

Eleven parts of MOCA (Du Pont's urethane crosslinker) at 250°F. (melted) was hand mixed into 100 parts of the urethane resin at 150°F. for 1 minute. This was the mixture poured on the fabric. Vibrathane(R) 6004 (a polyester) and Adiprene(R) L100 (a polyether) were the urethane resins used.

M. Fabric, Reinforcement for Vamp

The weights chosen were 3 oz./sq. yd. and 5 oz./sq. yd. These were felt to be the minimums for strength needed. Knit and woven nylon and polyester were tested.

N. Fabric, Liner Materials

The weights chosen here were 1.5 oz./sq. yd. and 3 oz./sq. yd. It was recognized that vamp and liner materials might be used for either or both purposes. Plain and twill woven nylon and polyester were chosen but twill woven polyester could not be obtained in these weights without special fabrication. Twill weave was chosen because of its stretch perpendicular to the twill.

O. Polyurethane Film, Exterior Coating for Boot Upper

The films were prepared by two component spraying. Polyurethane film 908 was made from mixing a 50% methyl ethyl ketone solution of Vibrathane B602 (polyether) which had two parts of Ferro(R) V780 black (on 100 parts of B602) with a 10% methyl ethyl ketone solution of MDA (methylene dianiline). The mix gave a 0.85 mole ratio of MDA to B602. This was sprayed on a lubricated metal surface and cured 16 hours at 160°F.

Polyurethane film 913 was prepared like 908. The 50% MEK solution of Vibrathane 6004 (polyester) also contained 2 parts Ferro V-780 black, 2 parts of CB-75 (a trifunctional isocyanate), and 2 parts of UV-24, an ultraviolet absorber. A 10% solution of MDA in MEK was used. Mix ratio was 0.85 mole ration MDA to 6004. Cure was 16 hours @ 160°F.

It should be pointed out that these films could also have cured at room temperature.

P. IIR Butyl Film, Exterior Coating for Boot Upper

Series 1025 was prepared with two different cure systems. Both A and B were first prepared without polyethylene and both stuck to the calender rolls very badly. The addition of three parts of polyethylene solved the sticking problem. The calendered sheets were cured 30'/320°F. in a press.

Q. EPDM Royalene Film, Exterior Coating for Boot Upper

Series 1027 was prepared with A as a lightly loaded and extended medium processing compound and B as a heavily loaded and extended good processing compound. Both A and B processed well. The calendered sheets in this case were cured in hot circulating air. The first cure was 30'/350°F. This was reduced to 30'/340°F. because of shrinkage.

R. CSM Hypalon Film, Exterior Coating for Boot Upper

Series 1028 was prepared with different loadings for abrasion differences. Both A and B were difficult to calender. It was necessary to add three parts of polyethylene to A to improve calendering. B was never calendered completely free of bubbles. The press cure of 30'/320°F., however, resulted in good films.

S. IM, Vistanex, Exterior Coating for Boot Upper

Series 1029 was never made successfully. Both A and B refused to bond in the Banbury and were mixed only with difficulty on the mill. The compounded material stuck to calender rolls. Series 1029 was abandoned in favor of a Neoprene film.

T. CR Neoprene Film, Exterior Coating for Boot Upper

Series 1039 was prepared with loading and plasticization differences. The films were prepared exactly as per formula directions without any problems arising.

U. Expanded Polyurethane, Insulation Only

When the Technical Proposal was written, it was thought that "know-how" to produce closed cell polyurethane in very low densities (2 to 4 lbs./cu. ft.) might be available. However, Du Pont's bulletin of March 6, 1961 "Microcellular Adiprene L Vulcanization" by D. F. Ritchie gives methods for sponge down to only 7 lbs./cu. ft. Since time did not permit the development of closed cell urethanes below this level, open cell polyurethane foam of 1.5 and 3 lbs./cu. ft. density was purchased from American Rubber Company in La Porte, Indiana for testing purposes.

V. New Polymeric Material

An interesting new polymeric material became available during the conduct of this program. It is tentatively described as a block copolymer of styrene and butadiene, which possesses rubber-like properties at room temperature, yet processes like a true thermoplastic at elevated temperatures. It is further unique in that the addition of vulcanizing agents is not required to render it elastic at normal temperatures.

Although an investigation of its suitability for footwear was not possible within the scope of this program, it is suggested as a candidate for future work.

Candidates for Initial Screening

A. Outsoles

1.	EPDM	Formula C-260-V6
2.	CR	" 1021A and 1021B
3.	NBR	" 1016A and 1016B
4.	IIR	" 1013A and 1013B
5.	CSM	" 1032E and 1032A
6.	PVC/NBR	" 1005A
7.	Polyurethane	" 726C
8.	Polyethylene	" 1023A

B. Midsoles/Insoles

1.	EPDM	Formula C-260-U6
2.	CR	" 1021C and 1021D
3.	NBR	" 1016C and 1016D
4.	IIR	" 1013C and 1013D
5.	CSM	" 1032B and 1032C
6.	PVC/NBR	" 1005B
7.	Polyurethane	" 93A
8.	Polyethylene	" 1023B and 1023C

C. Shank Supports

1. Stainless Steel - Type 304
2. Aluminum - Type 6061-T6
3. ABS - Kralastic MV and SRA
4. Acetal - Delrin
5. Nylon
6. Polycarbonate - Lexan

D. Reinforcement for Counter and Toe Cap

1. Semi-Rigid ABS	Formula 1035A
2. Rigid ABS	" 1034A
3. Woven Nylon 3.5376	Impregnated with polyurethane
4. a. Woven Dacron EXP FV1587	" " "
b. " " FV2994	" " "
5. Woven Glass 3.5011	" " "
6. Non-Woven Nylon SAN3500-RC1131	" " "
7. " " Dacron SAN3500-RC1252	" " "
8. " " Glass SP803	" " "
9. Lantuck Non-Woven 3-9027-1	" " "

E. Reinforcement for Vamp

1. Knit Nylon R5048
2. a. Knit Dacron 6440
   b. " " 6540
3. a. Woven Nylon 3.5310
   b. " " 3.5326
4. a. Woven Dacron 3.5440
   b. " " S/3582
   c. " " S/FV3796
   d. " " 15035
   e. " " 15302
   f. " " 15205

F. Liner

1. a. Plain Woven Nylon 3.5310
   b. " " " 3.5343
   c. " " " S/3465
   d. " " " S/3529

2. a. Twill Woven Nylon S/3029

   b. Twill Woven Nylon P9483

3. a. Plain Woven Dacron S/3458

   b. Plain Woven Dacron S/3471

   c. Plain Woven Dacron 3584

   d. Plain Woven Dacron 81450

   e. Plain Woven Dacron 81719

   f. Plain Woven Dacron 15035

   g. Plain Woven Dacron 15302

   h. Plain Woven Dacron 15205

G. Exterior Coating

1.	IIR	Formulas 1025A and 1025B
2.	EPDM	Formulas 1027A and 1027B
3.	CSM	Formulas 1028A and 1028B
4.	IM	Formulas 1029A and 1029B
5.	CR	Formulas 1039A and 1039B
6.	Polyurethane	Formulas 908 and 913

H. Insulation

1.	EPDM	Formula C-260-H6
2.	CR	Formulas 1021E and 1021F
3.	NBR	Formulas 1016E and 1016F
4.	IIR	Formula 1013E
5.	CSM	Formulas 1032D and 1032F
6.	PVC/NBR	Formula 1005C
7.	Polyurethane	Formulas 1.5 lbs./cu.ft. and 3 lbs./cu.ft.
8.	Polyethylene	Formulas 1023D and 1023E

Initial Screening

A. Outsoles

1. Paracril, Butyl, and PVC/NBR were dropped as candidates due to a tendency for compression set. This is not readily apparent from the data shown but was obvious from visual observations, which showed set in folded samples.

2. Polyethylene was dropped as a candidate due to excessive rigidity at high densities.

3. The cold crack test showed no differentiation. It was decided to replace this test with measurements of compression deflection at various temperatures.

4. Note that water absorption is reported both as lbs. of water absorbed per sq. ft. of cut surface and as the % weight change. Samples used in this test are cut 4-in. x 4-in. from the complete blown piece. Thus there is a skin on top and bottom which is less porous than the cut surface. Therefore, the thickness and weight of the sample can drastically affect the % weight change. Much greater emphasis was therefore placed on relative values of the lbs. of water absorbed per sq. ft. of cut surface than on % weight change.

B. Midsoles and Insoles

1. The observations made under outsoles, above, on Paracril, Butyl, PVC/NBR, Polyethylene, and the cold crack test were valid also for midsoles and insoles.

2. The polyurethane sample had excessive water absorption indicating a large percentage of open cells. It was decided to drop this particular expanded polyurethane formula. Note that this formula included Nitrosan blowing agent to achieve the lower density.

3. It was decided to keep polyurethane as a midsole/insole candidate using the same composition as the polyurethane outsole.

C. Shank Supports

Only stainless steel, aluminum alloy, and Acetal were retained as candidates due to flexural modulus. Preference was based on modulus with stainless steel first, aluminum second, and Acetal third.

D. Reinforcements for Counter and Toe Cap

Modulus of stiffness gave excellent differentiation between candidates. This can be seen from Figures 1 through 6. Only semi-rigid ABS, rigid ABS, and Lantuck impregnated with polyester polyurethane were retained as candidates. This was based on their even modulus of stiffness with temperature variation.

E. Reinforcement for Vamp

When the Technical Proposal was written, consideration was given to using a coated or impregnated fabric. The modulus of stiffness was decided upon as a screening test for this material. Further thought led to dropping the idea of coating. The modulus of stiffness test then became meaningless. Tongue tear was substituted as the initial screening test. 3.5310 (woven nylon), 81719 (woven Dacron), and 15205 (woven Dacron) all gave adequate tongue tears and were selected for second screening. 3-5326 (woven nylon) gave very good tear resistance also but since it was heavier it was dropped.

The 81719 was actually tested as a liner. However, as noted before, these fabrics should be interchangeable.

The knit Dacrons were received so late in the testing that they were submitted for initial, second, and final screening simultaneously. They proved to be deficient in tear, tensile, and water absorption.

F. Liner

The same three fabrics chosen for the vamp were also chosen for the liner for the same reasons. The 3.5310 had a high water absorption but the maximum total weight of water the vamp plus liner might absorb would be only (0.910 + 0.256) oz. x 31.7% = 0.37 oz. It was felt that this amount of water was small enough that the material should continue in test.

G. Exterior Coating for Boot Upper

The test results on these candidates did not clearly distinguish the best materials. All materials were therefore continued in testing. It was noted in both the Royalene and the Neoprene that the more heavily loaded and extended compounds had much poorer abrasion resistance. The outstanding abrasion resistance of polyurethane was noted.

H. Insulation for Boot Upper

1. Paracril and Butyl were discontinued because of compression set (folded sample).

2. PVC/NBR was retained as a candidate due to past USRC experience with this material.

3. A clear differentiation could not be made between the remaining candidates so all were continued in testing.

Candidates for Second Screening

A. Outsoles

1.	EPDM	Formula C-260-V6
2.	CR	Formulas 1021A and 1021B
3.	CSM	Formulas 1032E and 1032A
4.	Polyurethane	Formula 1011

B. Midsoles/Insoles

1.	EPDM	Formula C-260-U6
2.	CR	Formulas 1021C and 1021D
3.	CSM	Formulas 1032B and 1032C

C. Reinforcements for Counter and Toe Cap

1.	Semi-Rigid ABS	Formula 1035A
2.	Rigid ABS	Formula 1034A
3.	Lantuck 3-9027-1	Impregnated with Vibrathane 6004

D. Reinforcement for Vamp

1. Plain Woven Nylon 3.5310
2. a. Plain Woven Dacron 81719

   b. Plain Woven Dacron 15205
3. a. Knit Dacron 6440

   b. Knit Dacron 6540

E. Liner

1. Plain Woven Nylon 3.5310
2. a. Plain Woven Dacron 81719

   b. Plain Woven Dacron 15205

F. Exterior Coating

1.	IIR	Formulas 1025A and 1025B
2.	EPDM	Formulas 1027A and 1027B
3.	CSM	Formulas 1028A and 1028B
4.	CR	Formulas 1039A and 1039B
5.	Polyurethane	Formulas 908 and 913

G. Insulation

1.	EPDM	Formula C-260-H6
2.	CR	Formulas 1021E and 1021F
3.	CSM	Formula 1032
4.	Polyethylene	Formulas 1023D and 1023E
5.	Polyurethane	Formula 1.5 lbs./cu. ft. a 3 lbs./cu. ft.
6.	PVC/NBR	Formula 1005C and 1005D

Second Screening

A. Outsoles

Due to a lag in physical testing results all the remaining candidates were submitted for final screening. However, two conclusions can be drawn from the compression deflection versus temperature data:

1. Hypalon is very sensitive to temperature change, i.e., it stiffens too much at low temperature.

2. The Neoprene samples were too soft for adequate compression deflection comparison and would have to be reformulated for greater stiffness.

B. Midsoles and Insoles

All remaining candidates were submitted for final testing. Again Hypalon showed too much temperature sensitivity.

C. Reinforcements for Counter and Toe Cap

Lantuck impregnated with polyester urethane had both too high a density and too much water absorption. It had already been submitted for final screening before this was discovered.

D. Reinforcement for Vamp

These tests were previously made when the fabrics were tested for liners.

E. Liner

Taber abrasion showed 15205 (plain woven Dacron) to be the best fabric. 3.5310 (plain woven nylon) was better than 81719 and also lighter in weight.

F. Exterior Coating for Boot Upper

All remaining candidates were submitted for final tests before the second screening results were returned. These tests show Hypalon to be deficient in tear. The heavily loaded Royalene 1027B was somewhat deficient in both tensile and tear.

G. Insulation for Boot Upper

Compression deflection versus temperature again showed Hypalon to increase in stiffness much more rapidly from 0 F. to -20°F. than other materials. For this reason, Hypalon was dropped.

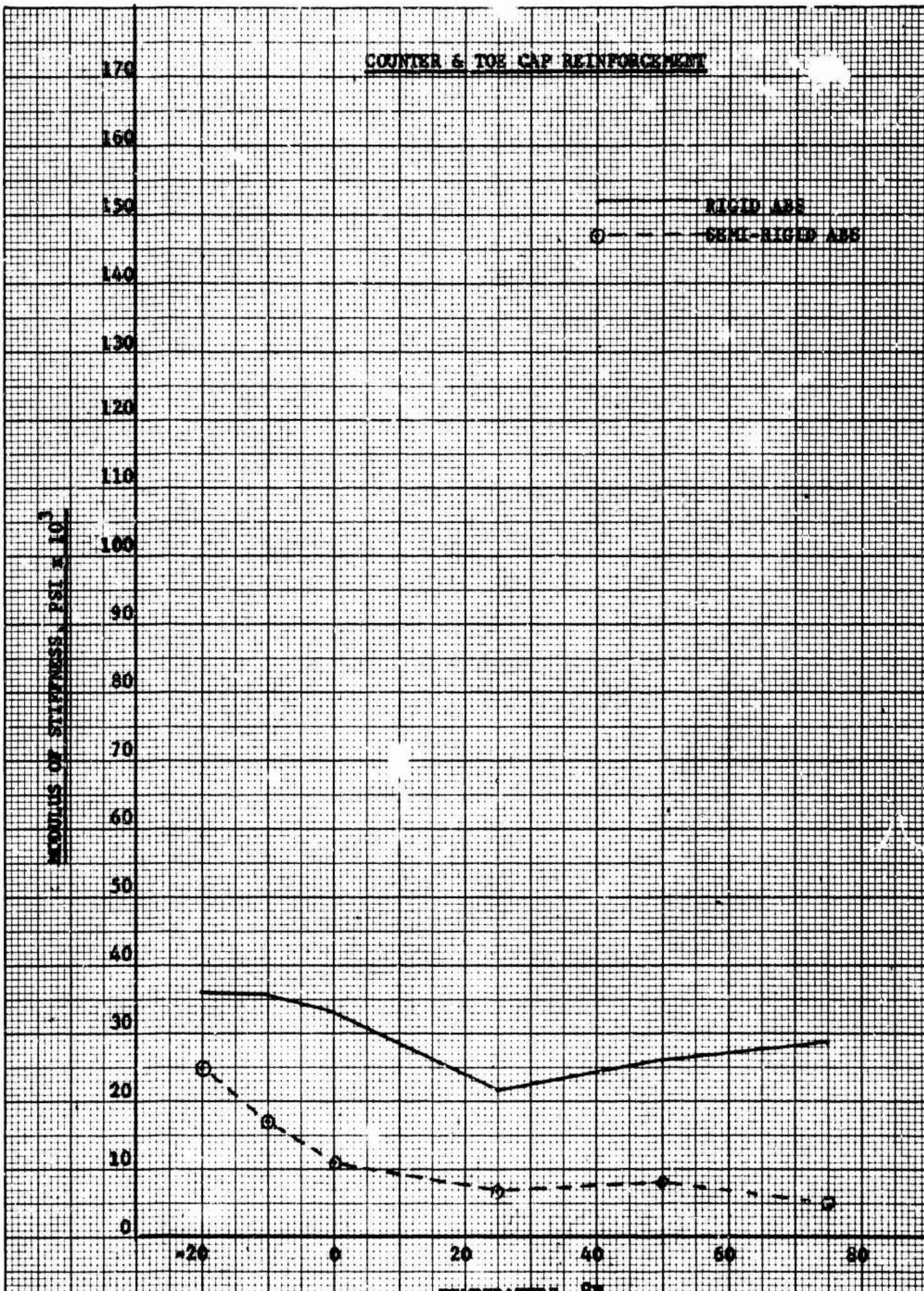
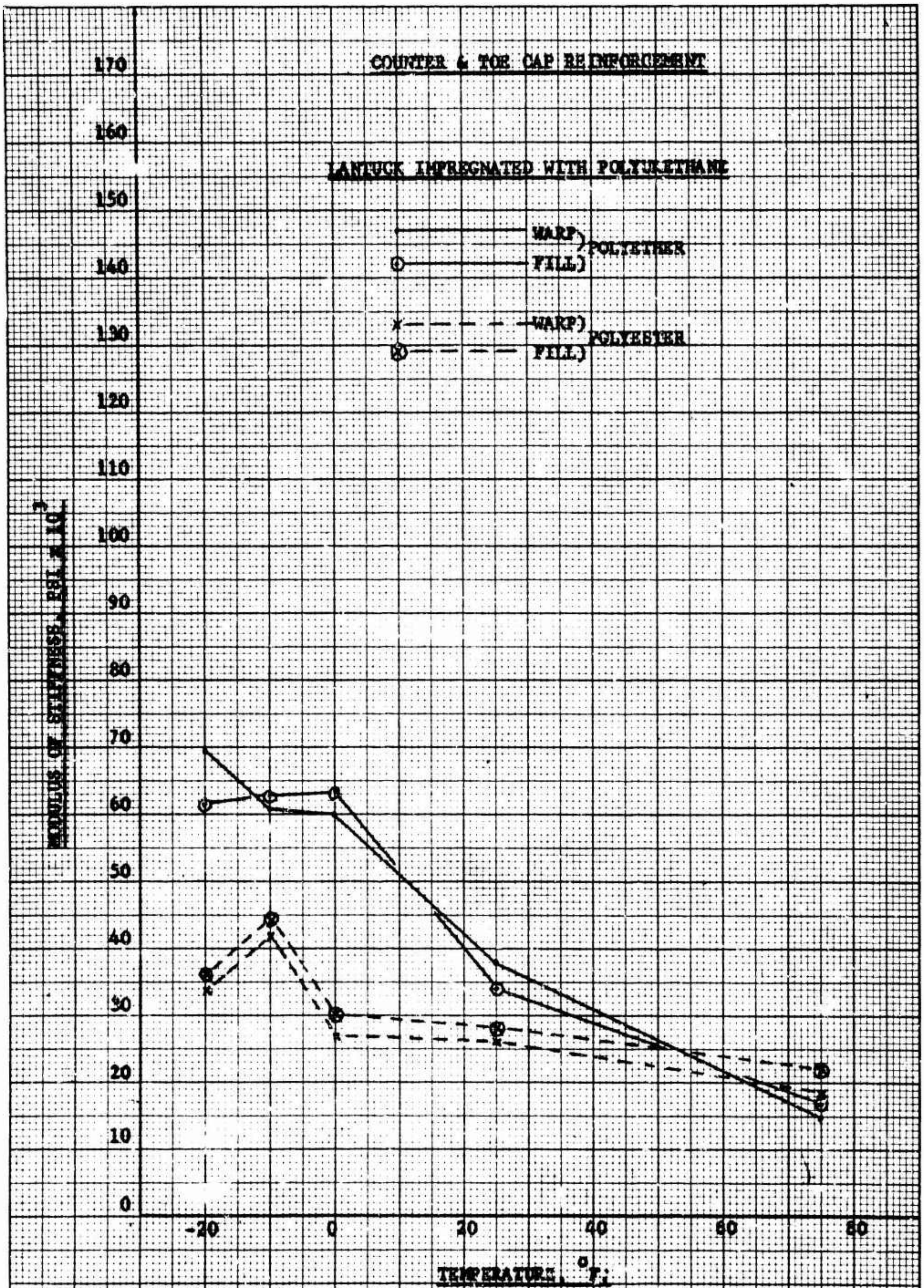

COUNTER & TOE CAP REINFORCEMENT
RIGID ABS
SEMI-RIGID ABS
MODULUS OF STIFFNESS, PSI x 10^3
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-20
0
20
40
60
80
TEMPERATURE, °F.

Figure 1


COUNTER & TOE CAP REINFORCEMENT
LANTUCK IMPREGNATED WITH POLYURETHANE
WARP) POLYETHER
FILL)
WARP) POLYESTER
FILL)
MODULUS OF STIFFNESS, PSI x 10^3
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-20
0
20
40
60
80
TEMPERATURE, °F.
Figure 2

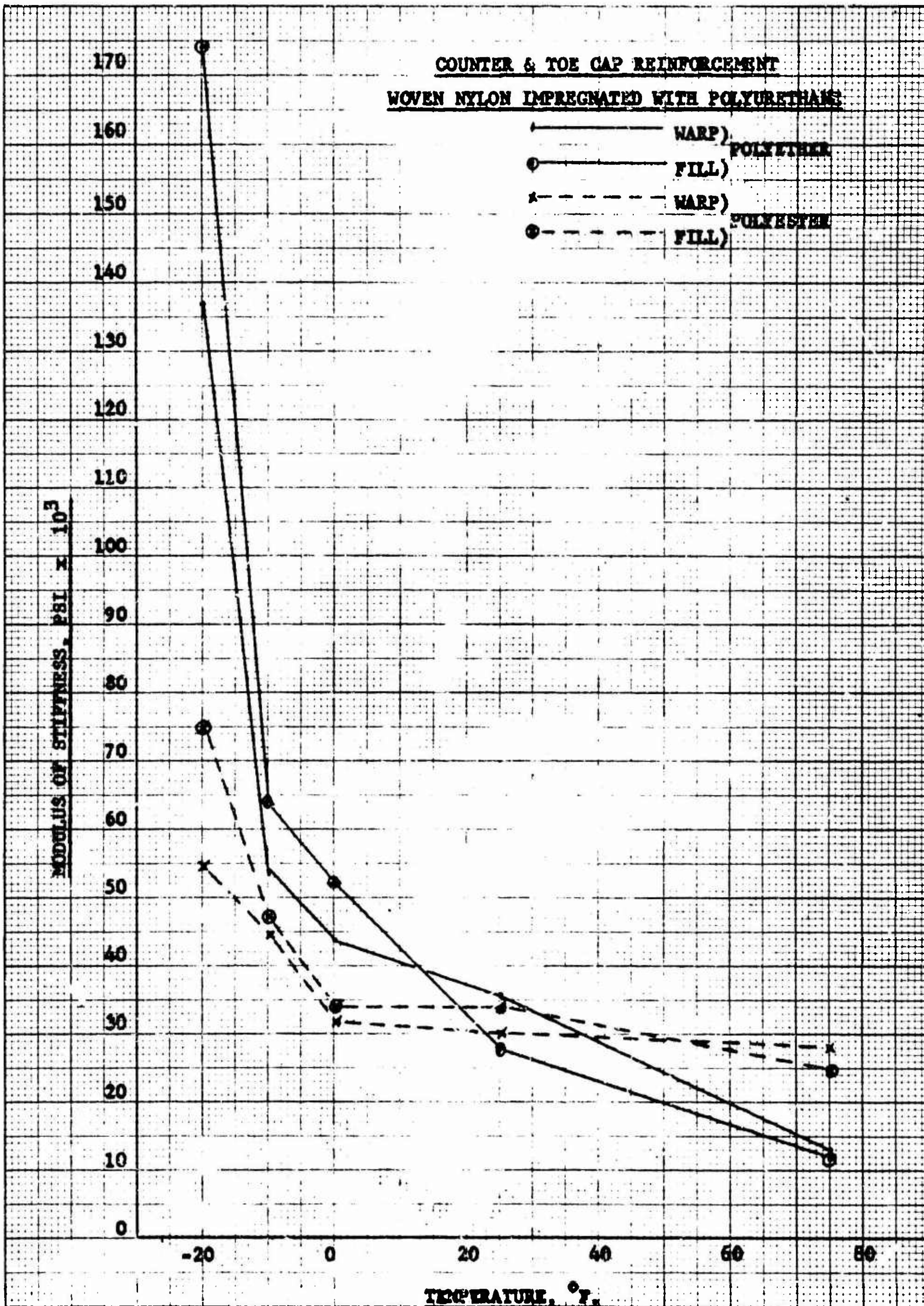
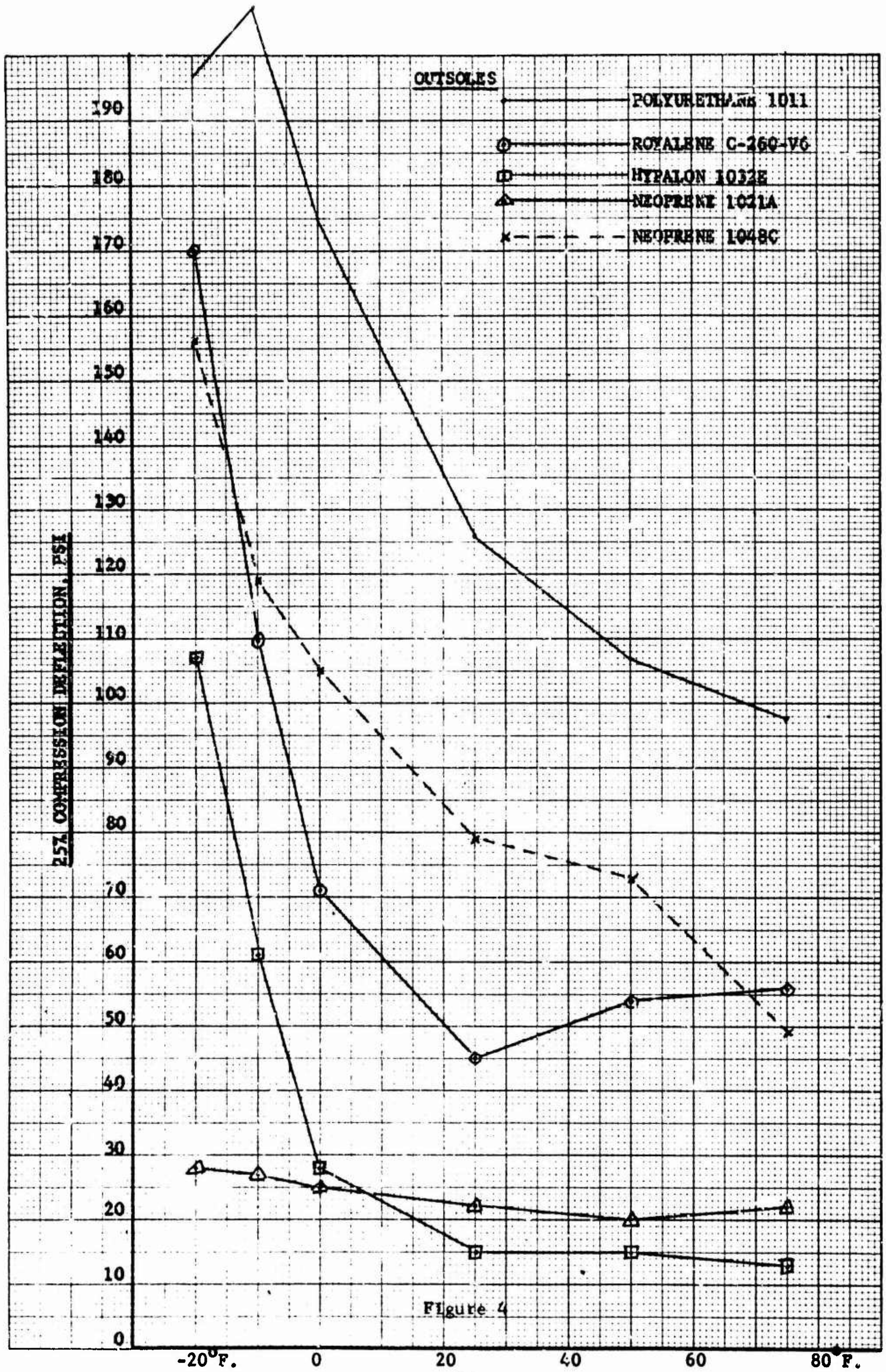

COUNTER & TOE CAP REINFORCEMENT
WOVEN NYLON IMPREGNATED WITH POLYURETHANE
WARP) POLYETHER
FILL)
WARP) POLYESTER
FILL)
MODULUS OF STIFFNESS, PSI x 10^3
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-20
0
20
40
60
80
TEMPERATURE, °F.

Figure 3



OUTSOLES
POLYURETHANE 1011
ROYALENE C-260-V6
HYPALON 1032E
NEOPRENE 1021A
NEOPRENE 1048C
25% COMPRESSION DEFLECTION, PSI
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-20°F.
0
20
40
60
80°F.

Figure 4

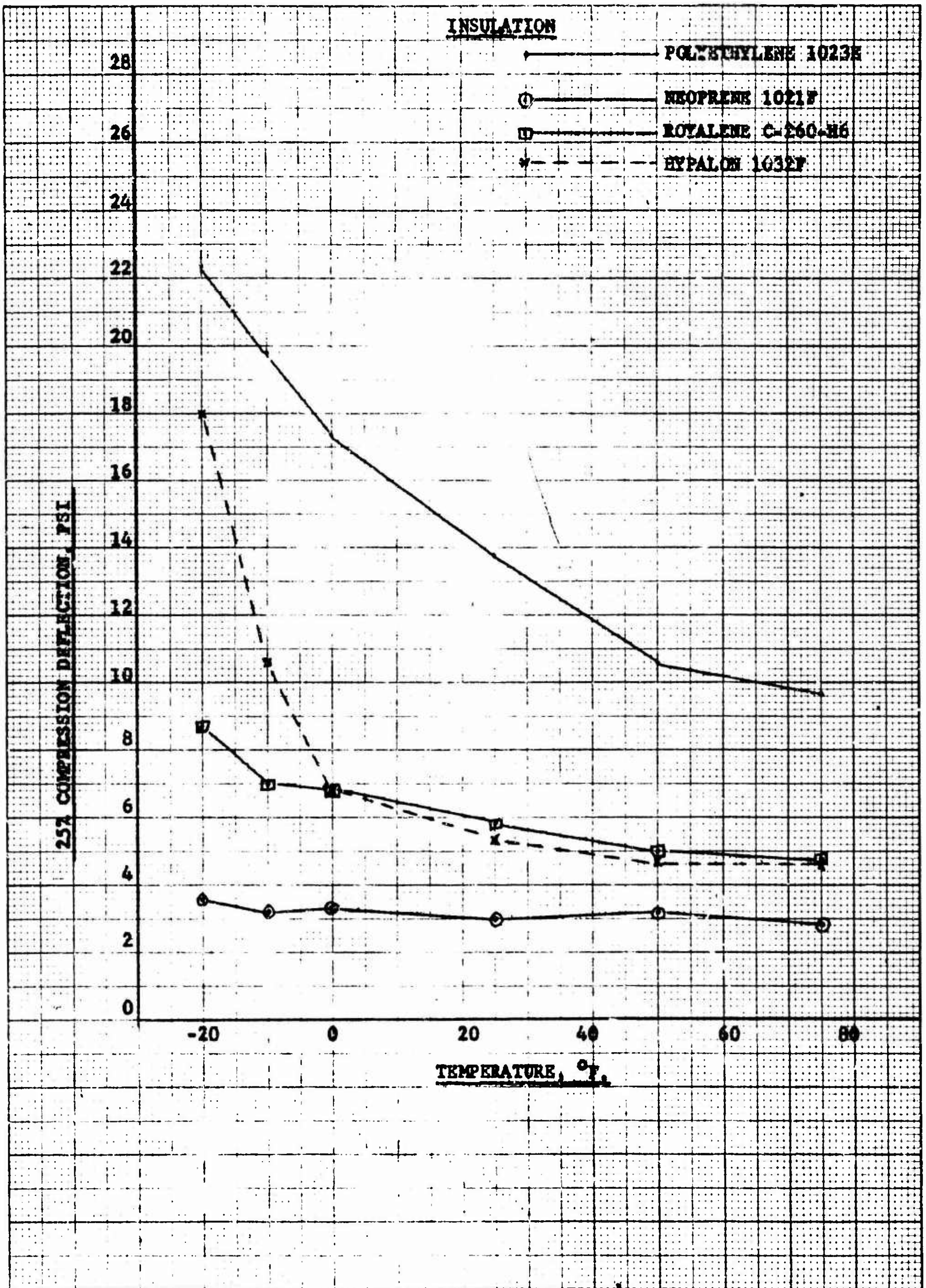

INSULATION
POLYETHYLENE 1023E
NEOPRENE 1021F
ROYALENE C-260-H6
HYPALON 1032F
25% COMPRESSION DEFLECTION, PSI
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-20
0
20
40
60
80
TEMPERATURE, °F.

Figure 5

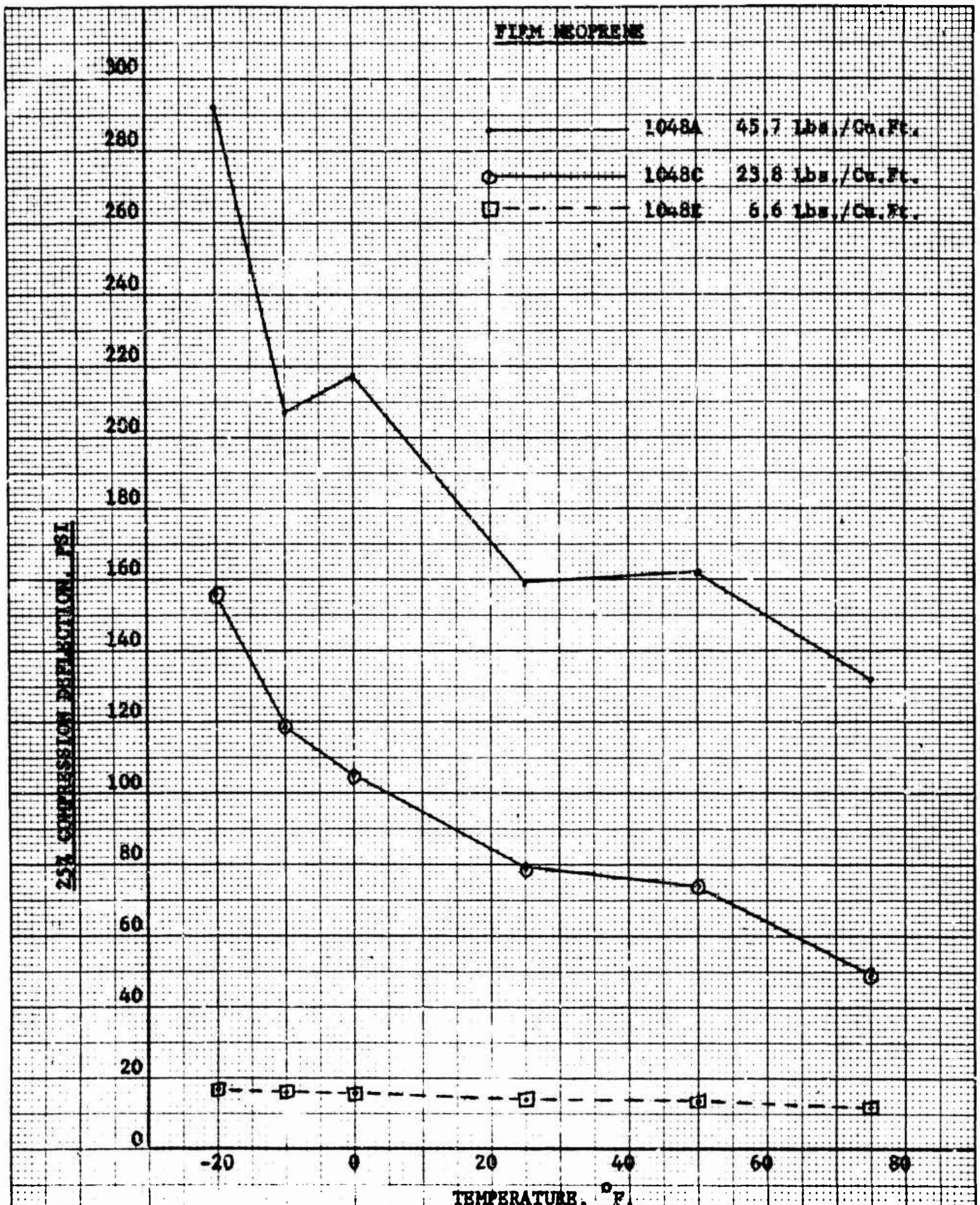

FIPM NEOPRENE
1048A 45.7 Lbs./Cu.Ft.
1048C 23.8 Lbs./Cu.Ft.
1048E 6.6 Lbs./Cu.Ft.
25% COMPRESSION DEFLECTION, PSI
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
0
20
40
60
80
TEMPERATURE, °F.

Figure 6

Adhesive Candidates

A. Bostik[R] 1225C - Urethane Base - United Shoe Machinery Corp.

B. U. S. Royal Adhesive S5006 - Neoprene Base

C. U. S. Royal Adhesive S5010 - Neoprene Base

D. U. S. Royal Adhesive S5200 - Synthetic Polymers Base

E. U. S. Royal Adhesive M6130 - Neoprene Rubber Base

F. U. S. Royal Adhesive M6200 - Urethane Base

G. U. S. Royal Adhesive M6230 - Nitrile Rubber Base

H. U. S. Royal Adhesive M6234 - Nitrile-Phenolic Base

I. U. S. Royal Adhesive M6300 - Neoprene Base

J. U. S. Royal Adhesive M6366 - Resin Modified Neoprene Base

K. U. S. Royal Adhesive M6594 - Modified Neoprene Base

Adhesives

During the second screening process, as the probable final candidates emerged, a list of adhesive candidates was chosen. Eleven commercially available materials were selected. The tests used were designed only to screen the candidates and not to furnish accurate adhesion data. The final selection was made in Phase 2 due to design and construction considerations. It was recognized at this time that screening only eleven materials from the thousands available might not be sufficient and that others might have to be tested in support of Phase 2 work. Samples 1-in. x 4-in. were cemented together along half their length. After a suitable cure time (dependent upon the cement) the samples were machine pulled in peel. Condition of the machine was such that the numbers generated are suitable only for comparison horizontally across the data sheets.

U. S. Royal Adhesives M6230, M6130, M6200 and Bostik 1225C were selected for Phase 2. During Phase 2 (Fabrication Studies) "Polygriptex" was qualitatively evaluated and found satisfactory for urethane to polyethylene adhesion. "Polygriptex" is a latex adhesive made by Adhesives Products Corp.

Candidates For Final Screening

A. Outsoles

1.	EPDM	Formula C-260-U6
2.	CR	Formulas 1021A and 1021B
3.	CSM	Formulas 1032E and 1032A
4.	Polyurethane	Formula 1012

B. Midsole/Insole

1.	EPDM	Formula C-260-U6
2.	CR	Formulas 1021C and 1021D
3.	CSM	Formulas 1032B, 1032C, and 1032D

C. Reinforcements For Counter and Toe Cap

1.	Rigid ABS	Formula 1034A
2.	Semi-Rigid ABS	Formula 1035A
3.	Lantuck	Polyurethane impregnated nonwoven fabric

D. Reinforcement for Vamp

1.	a.	Dacron-Knit	6440
	b.	Dacron-Knit	6540
2.		Nylon - Plain woven	3.5310
3.	a.	Dacron - Plain woven	81719
	b.	Dacron - Plain woven	15205

E. Liner

1.		Nylon - Plain woven	3.5310
2.	a.	Dacron - Plain woven	81719
	b.	Dacron - Plain woven	15205

F. Exterior Coating

1.	IIR	Formulas 1025A and 1025B
2.	EPDM	Formulas 1027A and 1027B
3.	CSM	Formulas 1028A and 1028B
4.	CR	Formulas 1039A and 1039B
5.	Polyurethane	Formulas 908 and 913

G. Insulation

1.	EPDM	Formulas C-260-H6
2.	CR	Formulas 1021E and 1021F
3.	Polyethylene	Formulas 1023D and 1023E
4	Polyurethane	1.5 lbs./cu. ft. and 3.0 lbs./cu. ft.
5.	PVC/NBR	Formulas 1005C and 1005D

Final Screening

A. Outsoles

1. Hypalon was eliminated due to its increase in stiffness with decrease in temperature.

2. Polyurethane was selected as the first choice for the following reasons·

   a. A pattern for good traction and weight reduction can be easily molded.

   b. Excellent abrasion resistance.

   c. Good thermal conductivity, weather resistance, oil resistance, and stiffness characteristics.

3. Neoprene was the second choice material due to good abrasion and temperature characteristics. It was recognized that series 1021, however, was too soft for outsoling. Series 1048, a firmer material to replace 1021, was prepared as written. 1048B, D and F with 25 parts

of polyethylene were difficult to mill and produced a rough surface when expanded so they were not tested. Thermal conductivities were better in 1048 and 1021. 1048C was chosen as the Neoprene candidate for Phase 2.

4. Royalene was the third choice material. EPDM was poorer in abrasion resistance, oil resistance, and thermal conductivity than Neoprene or polyurethane.

5. The abrasion test suggested in the Technical Proposal (USRC Tech. Spec. 10-7) could not be run on these expanded cellular materials. This test abrades a standard compound at the same time as the test sample so that variations in the abrasive and the like are cancelled. The expanded materials are so much softer than the standard that they are pulled from the test block by the abrader.

   Several abrasion test variations were tried as a substitute for USRC Tech. Spec. 10 - 7. The grams of weight lost after 300 cycles on the Taber Abrader using the H-18 wheel and a 1000 gram load seemed to differentiate between samples very well. This was adopted as the test.

6. Polyurethane was tested for tensile, elongation, and abrasion resistance after two weeks at 170°F. in 100% relative humidity. The properties retained appear to be sufficient. Note that the grams loss given is for 1000 cycles, not 300 cycles.

B. Midsoles and Insoles

1. Hypalon was dropped because of rapid increase in stiffness with decreasing temperature.

2. Polyurethane outsole material was used as first choice. It was hoped that the outsole, midsole, and the insole could all be molded in a single unit in this way.

3. Neoprene was second choice, since it is second for outsoles and insulation. For this material, it would be possible to use either the 1021 or 1048 series. However, 1021 was to be tried first.

4. Royalene was third choice. Note that the abrasion resistance of this material appears somewhat better than the 1021 Neoprene.

5. Note that the substitute abrasion test was used here also.

C. Reinforcements for Counter and Toe Cap

Series 1034A and 1035A were remade for the final screening. Lighter densities were obtained. There is little difference between the rigid and the semi-rigid ABS. Rigid ABS (1034A) was chosen as the single candidate since it is lower in density and thermal conductivity than 1035A.

D. Reinforcement for Vamp

15205, a plain woven Dacron, was the first choice final candidate because of good abrasion resistance, good tensile, and low water absorption. A plain woven Nylon 3.5310 was the second choice. 81719 was dropped since it was felt one Dacron candidate was enough.

E. Liner

The same fabrics were chosen for the liner as for vamp reinforcement for the same reasons.

Two other fabrics were tested during fabrication studies due to the poor lasting (fit on boot last) of the 15205 and 3.5310. These new samples were: Heiress Style Orlon knit about 5 oz./sq. yd. from Wm. Heller, Inc. and 3.5336 knit Nylon, a USRC Mishawaka Plant stock item.

F. Exterior Coating for Boot Upper

1. Polyether polyurethane (908) was the first choice for the following reasons:

   a. It can be applied easily as a spray.

   b. Excellent abrasion resistance.

   c. High modulus which tends to prevent puncture, scuffing, and tearing.

   d. Excellent aging resistance. Note that after aging for two weeks at 170°F. in 100% relative humidity very good tensile is retained with no loss in elongation, and there is very little loss in abrasion resistance.

   e. It can be applied to most materials without an adhesive.

   f. It will cure at room temperature.

   g. It can be used in thinner sheets, thereby saving weight.

2. Butyl (1025A) was the second choice because of very good abrasion resistance. Note that this is for this specific recipe. Typical polymer properties were not considered here.

3. Neoprene (1039A) was the third choice since its properties are well balanced. Also Neoprene is a candidate in all cellular components.

4. Royalene was dropped due to poor abrasion resistance and poor flexing.

5. Hypalon was dropped due to poor tear.

G. Insulation for Boot Upper

The first thermal conductivity determined on Royalene was sufficiently high to be suspect. It was decided to recheck all thermal conductivities on insulation.

It should be noted here that the thermal conductivities were determined on a Pittsburgh-Corning Thermal Conductivity Probe. This was used in preference to a guarded hot plate thermal conductivity apparatus. Our experience has shown that the two pieces of equipment give conductivities that agree within $\pm$ 0.02 BTU-in./hr./sq. ft./^{o}F.

Additional compression set tests were run for clarification on this property. A description of the tests is given below.

Folded tests were made on 1-in. x 4-in. samples. Liner fabrics, polyurethane exterior film, insulation free of coating, and insulation with fabric on one side and polyurethane film on the other were all tested. Fabric and urethane film were adhered to the insulation with U. S. Royal M6200 Adhesive. Insulations were tested about 1/8-in. thick.

The samples were bent 180^{o} and held between tongue depressors by rubber bands. One set of samples was held two weeks at room temperature and then released. The other set was aged 22 hours at 158^{o}F. and then released. Visual observation was the principle judgement criterion though some semi-quantitative return data are recorded in the data section.

Conventional compression sets were also checked at 25% and 50% deflection and at room temperature and after 22 hours at 158^{o}F. These were instructive.

From the test data gathered including the extra tests the following selections and conclusions were made:

1. PVC/NBR was dropped due to high compression set. This was true in both conventional and in the folded tests.

2. Polyurethane open cell foam was dropped because of the following:

   a. The danger of puncture of any covering films which might allow the foam to absorb water and lose its insulating quality.

   b. The severe set noted in the folded samples which were coated with liner fabric and exterior film. This was surprising since conventional compression set was excellent.

   c. The difficulty of applying adhesive to the foam to attach liner and exterior.

3. Polyethylene (10[illegible]3E) was the first choice due to its resistance to folded and conventional compression set. The resistance to folded set is probably partially due to its higher compression deflection resistance. This firmness should be an aid in preventing folds in a boot. Water absorption values were also the best of the candidates.

   The compression set after 158^{o}F. aging was extremely high but the values for all of the closed cell materials after 158^{o}F. aging were high. High compression sets are typical of light density closed cell products and polyethylene appears to be as good as the other materials.

4. Neoprene was the second choice based on thermal conductivity and probable ease of adhering other components to it. Water absorption was adequate.

   It should be noted that water absorption in lbs./sq. ft. of cut surface is a much better criterion than % change since sample shape and weight can alter the % change drastically.

5. Royalene was the third choice candidate for its balanced properties. The possibility of greater adhesion problems with EPDM than with other materials prevented it from becoming the second choice.

6. The folded samples which had fabric on one side and polyurethane film on the other were much stiffer than anticipated. This was due to the M6200 Adhesive. The adhesive has penetrated the fabric and the high modulus of the urethane (from M6200) added to the stiffness.

   This points out the care which must be exercised in using adhesive in building the boot. It also indicates that a low modulus adhesive should be used.

Calculations For Design of Components

Data analysis was essentially a matter of judgement. There are some instructive calculations which can be made, however, and these are given below.

1. Sole Thickness

   Assume that all heat from the foot (ankle to sole) is transferred through the boot sole.

   Assume starting skin temperature = $86^\circ F.$

   Assume a fair degree of foot comfort at a skin temperature of $60^\circ F.$

   Assume specific heat of foot = 0.7.

   Assume foot weight (ankle to sole) = 2 Lbs.

   Thermal conductivity of boot sole = 0.430 BTU/in./hr./ft.^{2}/$^\circ$F.

   Boot sole thickness = 0.5 in.

   Elapsed time = 2 Hrs.

   Boot sole area = 32.6 sq. in. = 0.226 sq. ft.

   The average temperature difference then is:

$$\frac{(86^\circ F. \text{ to } -20^\circ F.) + (60^\circ F. \text{ to } -20^\circ F.)}{2} = 93^\circ F.$$

   Then the heat that can transfer through the boot sole is:

$$\frac{0.430 \text{ BTU/in./hr./ft.}^2/^\circ F. \times 2 \text{ hr.} \times 0.226 \text{ ft.}^2 \times 93^\circ F}{0.5 \text{ in.}} = 36.1 \text{ BTU}$$

   Heat available from the foot is

$$2 \times 0.7 \times (86^\circ F. - 60^\circ F.) = 36.4 \text{ BTU}$$

   The above does not consider the additional insulating value of a sock.

   Tests on USRC footwear indicate that fair foot comfort is maintained as low as $54^\circ F.$ which adds an additional factor of safety.

   Since the skin temperature at the start of 2 hrs. of inactivity may be below $86^\circ F.$, it is probable that total boot soling thickness should be about 0.6 in.

2. Boot Component Weights

a. Outsole, Midsole, and Insole, all polyurethane at 24 lbs./cu. ft.

$$\frac{24 \text{ lbs./cu.ft.} \times 0.6 \text{ in.} \times 32.6 \text{ sq.in.} \times 16 \text{ oz./lb.}}{1728 \text{ cu. in./cu. ft.}} = 4.35 \text{ oz.}$$

b. Insulation, polyethylene at 3.1 lbs./cu. ft.

$$\frac{3.1 \text{ lbs./cu.ft.} \times 0.125 \text{ in.} \times 206 \text{ sq.in.} \times 16 \text{ oz./lb.}}{1728 \text{ cu. in./cu. ft.}} = 0.74 \text{ oz.}$$

c. Liner, 3.3 oz./sq. yd. fabric

3.3 oz./sq. yd. x 0.182 sq. yd. = 0.60 oz.

d. Vamp, 3.3 oz./sq. yd. fabric

3.3 oz./sq. yd. x 0.032 sq. yd. = 0.11 oz.

e. Exterior, polyurethane (908) at 0.015 in.

$$0.159 \text{ sq. yd.} \times 0.015 \text{ in.} \times \frac{1 \text{ oz./sq. yd.}}{0.001 \text{ in.}} = 2.39 \text{ oz.}$$

f. Counter and Toe Cap, Rigid ABS at 12.9 lbs./cu. ft.

$$\frac{12 \text{ lbs./cu. ft.} \times 0.125 \text{ in.} \times 42.7 \text{ sq.in.} \times 16 \text{ oz./lb.}}{1728 \text{ cu. in./cu. ft.}} = 0.60 \text{ oz.}$$

g. Shank Support, Stainless Steel at 11.61 gm./sq.in.

$$\frac{11.61 \text{ gms./sq.in.} \times 1 \text{ sq.in.}}{28.4 \text{ gms./oz.}} = 0.41 \text{ oz.}$$

h. Total Boot Weight

Soles	4.35 oz.
Insulation	0.74 oz.
Liner	0.60 oz.
Vamp	0.11 oz.
Exterior	2.39 oz.
Counter and Toe Cap	0.60 oz.
Shank Support	0.41 oz.
	9.20 oz.

i. Total Allowance for Adhesives, Fasteners, and the Unforeseen

15 oz. -9.20 oz. = 5.8 oz.

3. Variation in Compression Deflection with Temperature

$$\frac{\text{Compression Deflection at } -20^{\circ}\text{F.}}{\text{Deflection at } 75^{\circ}\text{F.}} = \text{X Compression}$$

For Neoprene Soling Series 1048

1048A density 45.7 lbs./cu. ft.

293/132 = 2.22

1048C density 23.8 lbs./cu. ft.

156/49 = 3.18

1048E density 5.6 lbs./cu. ft.

17/12 = 1.42

Similar calculations can be made for the other candidate formula series with similar results. This indicates that low densities are less affected by low temperature. It also indicates that the relationship between temperature stiffening and density is non-linear.

Recipes, Processes and Test Results

Tables 1 to 25 give the formulas and processes used. Tables 26 to 33 show Initial Screening Physical Test Results; Tables 34 to 40 show the Second Screening Physical Test Results; Tables 41 to 47, Final Screening Physical Test Results; Tables 48 to 52, Extra Physical Test Results; and Table 53 shows Adhesives Tests.

TABLE 1

SERIES C-260. EPDM, SOLES AND INSULATION

	H6-1	U6-1	V6-1
Royalene 301	40.0	40.0	62.5
Zinc Oxide	3.0	3.0	3.0
Stearic Acid	1.0	1.0	1.0
Varox	3.0	3.0	3.0
Celogen AZ	10.0	7.0	6.0
Polyethylene DYNH-3	60.0	60.0	30.0
Blue G Whiting	40.0	40.0	-
Lamp Black	-	-	0.5
Pliolite S-6 or Kralac "A" (R)	-	-	7.5
Silene EF (R)	-	-	40.0
	157.0	154.0	153.5

1. Banbury mix all ingredients except Varox and Celogen AZ. Mix to a temperature rise to 270°F. (4 - 5 min.).
2. Dump and slab off sheeting mill with rolls at 120°F.
3. Add Celogen AZ and Varox on a mill with rolls at 80 - 100°F.
4. Calender with warming mill rolls at 80 - 100°F. and calender rolls at 80°F.
5. Press pre-cure 12 min. at 320°F. Pressure at start 1500 PSI and rise to 5000 PSI. Cool in mold.
6. Expand in hot air 10 minutes at 300°F.

TABLE 2

SERIES 1006, CR NEOPRENE, SOLES AND INSULATION

	A	B	C	D	E	F	MINUTES
Neoprene W	100.0	→	→	→	→	→	0
Neophax A (R)	7.0	→	→	→	→	→	0
Magnesium Oxide ELC	4.0	→	→	→	→	→	0
SRF Black	42.5	42.5	42.5	42.5	30.0	30.0	2
Neozone D (R)	2.0	→	→	→	→	→	2
Flexol TOF (R)	22.0	22.0	22.0	22.0	25.0	25.0	3
Antimony Oxide	10.0	10.0	10.0	10.0	-	-	3
Paraffin Oil	7.0	7.0	7.0	7.0	2.0	2.0	4
Retarder W	1.0	→	→	→	→	→	4
Stearic Acid	0.5	→	→	→	→	→	4
Celogen AZ	3.0	4.0	6.0	8.0	6.0	8.0	6
Zinc Oxide	5.0	→	→	→	→	→	6
Diethyl Thiourea	-	-	-	-	0.1	0.1	8
Permalux (R)	0.5	0.5	0.5	0.5	-	-	8
	204.5	205.5	207.5	209.5	162.6	164.6	10 Dump

1. Banbury mix using indicated times and a temperature below 200°F.

Note: No satisfactory cure and expansion were found for this series and it was abandoned.

TABLE 3

SERIES 1015, CR NEOPRENE, SOLES AND INSULATION

	A	B	C	D	E	F
Neoprene W	100.0	→				
Neozone D	2.0	→				
Neophax A	7.0	→				
ELC Magnesia	4.0	→				
SRF Black	42.5	→				
Flexol TOF	22.0	→				
Paraffin Oil	7.0	→				
Antimony Oxide	10.0	→				
Retarder W	1.0	→				
Stearic Acid	0.5	→				
Zinc Oxide	5.0	→				
Celogen AZ	3.0	5.0	7.0	9.0	12.0	15.0
NA22	0.3	→				
Diethyl Thiourea	0.1	→				
	204.4	206.4	208.4	210.4	213.4	216.4

1. Mill mix on a cold mill.

Note: No satisfactory cure and expansion were found for this series and it was abandoned.

TABLE 4

SERIES 1021, CR NEOPRENE, SOLES AND INSULATION

	A	B	C	D	E	F
Neoprene W	100.0	→				
Neozone D	2.0	→				
Neophax A	7.0	→				
BLC Magnesia	4.0	→				
SRF Black	42.5	→				
Flexol TCP	22.0	→				
Paraffin Oil	7.0	→				
Antimony Oxide	10.0	→				
Retarder W	1.0	→				
Stearic Acid	0.5	→				
Zinc Oxide	5.0	→				
Celogen AZ	3.0	5.0	7.0	9.0	12.0	15.0
Thionex	1.0	→				
DOTG	1.0	→				
Sulfur	1.0	→				
	207.0	209.0	211.0	213.0	216.0	219.0

1. Mill mix on a cold mill.

2. Slab off mill to fit Chelsea frame.

3. Press pre-cure in a gasketed frame 4000 psi/18'/300°F. Cool in press. Expand 15'/340°F.

TABLE 5

SERIES 1007, NBR PARACRIL, SOLES AND INSULATION

	A	B	C	D		
Paracril 18-80	100.00	→	→	→	0'	Part I
Agerite Stalite	1.00	→	→	→	5'	
	101.00	101.00	101.00	101.00	15' Dump	
Purecal T	50.00	→	→	→	Part II	
Titanox RANC	5.00	→	→	→		
Zinc Oxide	5.00	→	→	→		
Sulfur	1.00	→	→	→		
MBTS	0.25	→	→	→		
Stearic Acid	1.00	→	→	→		
Plastolein(R) 9058	30.00	→	→	→		
	92.25					
Celogen AZ	3.00	5.00	10.00	15.00	Part III	
	196.25	198.25	203.25	208.25		

1. Make a Banbury masterbatch of Part I using indicated times with full cooling water on and slow speed.
2. Make a Hobart masterbatch of Part II. Blend dry ingredients together for 5 min., then add Plastolein 9058 and blend another 5 min.
3. Blend Part III into Part II in a Hobart mixer. Mix at least 5 min.
4. Band the Paracril masterbatch on a cold mill. Add Part III slowly. Work the compound 10 minutes after Part III has been mixed into the gum. Slab off and cool.
5. Rest 8 hours before further use.

NOTE: A satisfactory cure and expansion could not be found for this series and it was abandoned.

TABLE 6

SERIES 1016, NBR PARACRIL, SOLES AND INSULATION

	A	B	C	D	E	F	
Paracril 18-80	100.0	→					) Part I
Agerite Stalite	1.0	→					)
	101.0	101.0	101.0	101.0	101.0	101.0	
Purecal T	50.0	→					)
Titanox RANC	5.0	→					)
Zinc Oxide	5.0	→					) Part II
Stearic Acid	1.0	→					)
Plastolein 9058	30.0	→					)
	91.0	91.0	91.0	91.0	91.0	91.0	
Vultac (R) #3	4.0	→					) Part III
Celogen AZ	3.0	5.0	7.0	9.0	12.0	15.0	)
	7.0	9.0	11.0	13.0	16.0	19.0	
Total Parts	199.0	201.0	203.0	205.0	208.0	211.0	

1. Make a Hobart mix masterbatch of Part II. Mix dry ingredients first for 5 minutes. Then add Plastolein 9058 and mix another 5 minutes.

2. Mix Parts I and II on a cool mill. Make sure that Part I is well broken before adding Part II. This is the masterbatch.

3. Mix Part III into the masterbatch on a cold mill.

4. Calender with top roll about 140^{o}F., middle roll about 130^{o}F., and bottom roll cold.

5. Press pre-cure in a gasketed Chelsea frame at 4000 psi/25'/300^{o}F. Cool in press. Expand 15'/340^{o}F.

TABLE 7

SERIES 1013, IIR BUTYL, SOLES AND INSULATION

	A	B	C	D	E	F	
Butyl #365	100.0	→	→	→	→	→	Part I
Alathon (R) Polyethylene	25.0	→	→	→	→	→	
	125.0	→	→	→	→	→	
Part I	125.0	→	→	→	→	→	Part II
SRF Black	40.0	40.0	-	-	-	-	
TiPure (R) R-610	-	-	20.0	20.0	60.0	60.0	
Polycin (R) 783	10.0	10.0	10.0	10.0	-	-	
Neophax A	-	-	-	-	15.0	15.0	
Petrolatum	30.0	30.0	10.0	10.0	10.0	10.0	
Stearic Acid	1.0	1.0	1.0	1.0	3.0	3.0	
Zinc Oxide	5.0	→	→	→	→	→	
ESEN	1.0	→	→	→	→	→	
3445 Wax	-	-	-	-	3.0	3.0	
	212.0	212.0	172.0	172.0	222.0	222.0	
Part II	212.0	212.0	172.0	172.0	222.0	222.0	Part III
GMF	2.0	2.0	2.0	2.0	3.0	3.0	
Sulfur	2.0	2.0	2.0	2.0	3.0	3.0	
MBTS	4.0	4.0	2.0	2.0	1.0	1.0	
Sulfasan (R) R	-	-	2.0	2.0	3.0	3.0	
Celogen AZ	8.0	5.0	10.0	7.0	12.0	16.0	
	228.0	225.0	190.0	187.0	244.0	248.0	

1. Band polyethylene on the mill. Add the Butyl to the polyethylene, cooling the mill as Butyl is added. Sheet out and cool.
2. Mill mix Part II on a cool mill. Sheet out and cool.
3. Mill mix Part III on a 140°F. mill. Sheet out and cool.
4. Calender with top roll 140°F., middle roll 130°F., and bottom roll cold.
5. Press pre-cure in a gasketed Chelsea as follows:

   A 4000 psi/5'/280°F.
   B,C,D,E 4000 psi/7½'/280°F.
   Cool in press.
6. Expand A, B, C, and D 20'/340°F. Expand E 15'/340°F.

TABLE 8

SERIES 1020, CSM HYPALON, SOLES AND INSULATION

	A	B	C	D	E	F	
Hypalon 20	50.0	→					
" 40	50.0	→					
Staybelite(R) Resin	2.5	→					
Neophax A	15.0	→					Part I
Vistanex L-120	60.0	→					
Polyethylene AC 617	3.0	→					
Petrolatum	5.0	→					
	185.5	→					
Part I	185.5	→					
Magnesia ELC	20.0	→					
NBC	3.0	→					
SRF Black	20.0	20.0	-	-	-	-	
FT Black	-	-	20.0	20.0	20.0	20.0	Part II
Kenflex(R) N	40.0	→					
Celogen AZ	6.0	8.0	8.0	10.0	16.0	20.0	
Tetrone(R) A	1.0	→					
	275.5	277.5	277.5	279.5	285.5	289.5	

1. Mill mix Part I masterbatch using cold water on the rolls. Mix for at least 10 minutes after all materials are dispersed. Sheet out 4 times through a tight mill.

2. Mill mix Part II using cold water on the rolls. Mix for at least 10 minutes after materials are dispersed. Sheet out 4 times through a tight mill.

3. Calender using rolls as cold as possible.

4. Note: Satisfactory cure and expansion could not be found for this series, and it was abandoned.

TABLE 9

SERIES 1031, CSM HYPALON, SOLES AND INSULATION

	A	B	C	D	E	F	
Hypalon 20	50.0	→					Part I
" 40	50.0	→					Part I
Staybelite Resin	2.5	→					Part I
Neophax A	15.0	→					Part I
Alathon 10 Polyethylene	25.0	→					Part I
	142.5	→					Part I
Part I	142.5	→					Part II
Magnesia BLC	20.0	→					Part II
Zinc Oxide	5.0	→					Part II
Stearic Acid	2.0	→					Part II
NBC	3.0	→					Part II
SRF Black	20.0	→					Part II
Sundex(R) 790	40.0	→					Part II
Celogen AZ	4.0	6.0	8.0	10.0	-	-	Part II
Tetrone A	1.0	→					Part II
	237.5	239.5	241.5	243.5	-	-	Part II

1. Mill mix Part I masterbatch. Get temperature to about 250°F. before adding polyethylene. Mix at least 10 minutes after materials are dispersed. Slab off and cool.

2. Mill mix Part II on a cool mill (100 - 150°F.). Mix for at least 10 minutes after materials appear dispersed. Slab off and cool.

NOTE: This series was abandoned due to cure.

TABLE 10

SERIES 1032, CSM HYPALON, SOLES AND INSULATION

	A	B	C	D	E	F	
Hypalon 20	50.0	→					Part I
" 40	50.0	→					Part I
Staybelite Resin	3.0	→					Part I
Neophax A	15.0	→					Part I
Alathon 10 Polyethylene	25.0	→					Part I
	143.0	→					Part I
Part I	143.0	→					Part II
Sublimed Litharge	20.0	→					Part II
Zinc Oxide	5.0	→					Part II
Stearic Acid	2.0	→					Part II
FT Black	20.0	→					Part II
Sundex 790	40.0	→					Part II
Celogen AZ	4.0	6.0	8.0	10.0	2.0	12.0	Part II
MBTS	1.0	→					Part II
Tetrone A	1.0	→					Part II
	236.0	238.0	240.0	242.0	234.0	244.0	Part II

1. Band polyethylene on mill.

2. Add Hypalon to polyethylene. Cool rolls as possible while adding Hypalon. Mix at least 10 minutes after all ingredients (Part I) appear dispersed. Slab off and cool.

3. Mill mix Part II on a cool mill (100 - 150°F.). Mix for at least 10 minutes after all ingredients appear dispersed. Slab off and cool.

4. Mill to necessary thickness for Chelsea frame.

5. Press pre-cure in a gasketed Chelsea frame at 4000 psi/13'/280°F. Cool in press. Expand 20'/340°F.

TABLE 11

SERIES 1005, PVC/NBR, SOLES AND INSULATION

	A	B	C	D			MINUTES
Paracril C	100.0	100.0	-	-	)		0
Paracril 18-80	-	-	100.0	100.0	)		0
Agerite Stalite	1.0	1.0	1.0	1.0	)	Part I	4
Excelsior Black	0.1	0.1	-	-	)		4
	101.1	101.1	101.0	101.0	)	Dump	12
Part I	101.1	101.1	101.0	101.0	)		0
Vinylite(R) VYNW	100.0	100.0	-	-	)		1
Marvinol(R) VR33	-	-	100.0	100.0	)		1
Zinc Oxide	5.0	5.0	5.0	5.0	)		1
Antimony Oxide	-	-	20.0	20.0	)		1
Titanox RANC	7.0	7.0	-	-	)		1
BI Whiting	-	-	20.0	20.0	)	Part II	1
Plasticizer L727	27.0	25.0	38.0	35.0	)		1
Monoplex(R) S-73	-	-	30.0	30.0	)		1
Vanstay L	4.0	4.0	6.0	6.0	)		1
Calcium Stearate	2.0	2.0	4.0	4.0	)		1
Stearic Acid	2.0	2.0	-	-	)		1
Polycin 783	-	-	5.0	5.0	)		1
	248.1	246.1	329.0	326.0	)	Dump	13
Celogen OT	10.0	15.0	-	-	)		
Celogen AZ	-	-	18.0	26.0	)	Part III	
Plasticizer L727	4.0	6.0	7.0	10.0	)		
	14.0	21.0	25.0	36.0	)		

TABLE 11 (Cont'd)

	A	B	C	D		
Part II	248.1	246.1	329.0	326.0	)	
Part III	14.0	21.0	25.0	36.0	)	
Vultac #3	4.0	4.0	2.0	2.0	)	
MBTS	0.5	0.5	-	-	)	Part IV
Bismate (R)	-	-	1.0	1.0	)	
OXAF (R)	-	-	1.0	1.0	)	
	266.6	271.6	358.0	366.0	)	

INSTRUCTIONS

1. Banbury mix Part I at about 290°F. using indicated times.
2. Hobart mix all ingredients of Part II except Part I.
3. Banbury mix Part II using indicated times and temperature of 300°F.
4. Hobart mix Part III.
5. Mill mix Part IV on a mill about 150°F. Mix at least 10 min. after all ingredients appear dispersed.
6. Calender with top roll 140 - 160°F., middle roll 130 - 140°F., and bottom roll cold.
7. Press pre-cure A and B in a gasketed Chelsea at 4000 psi/40'/303°F. Cool in press. Expand 15'/340°F.
8. Press pre-cure C and D in a gasketed Chelsea at 4000 psi/30'/300°F. Cool in press. Expand 15'/340°F.

TABLE 12

EXPANDED POLYURETHANE, OUTSOLES 1012A

MATERIAL	PARTS
Adiprene L167	100.00
MOCA	19.00
Silicone L5310	1.80
Water	0.18
Dabco(R) 33LV	0.54
Black Pigment	0.30
	121.82

1. Mix the above with conventional urethane mixing equipment.

2. Pour into mold.

3. Cure 30 min. at 250°F.

4. Post cure 24 hours at 212°F.

NOTE: This compound was selected as the primary candidate for both outsoles and midsoles/insoles in Section 2, Fabrication Studies.

TABLE 13

EXPANDED POLYURETHANE, MIDSOLE-INSOLE, SERIES 1012B

MATERIAL	PARTS
Adiprene L167	125.0
MOCA	24.0
SF 1079	4.0
Nitrosan Dispersion	15.0
Black 1570	0.3
	168.3

1. Spray mold with Hypalon skin forming material.
2. Mix the above compound and pour into mold.
3. Cure 30 min. at 250°F.
4. Post cure 24 hours at 212°F.

NOTE: This compound exhibited high water absorption and was dropped from further consideration.

TABLE 14

SERIES 1023, POLYETHYLENE, SOLES AND INSULATION

	A	B	C	D	E
Polyethylene DYNK	100.0	→	→	→	→
Stearic Acid	2.0	→	→	→	→
Zinc Oxide	3.0	→	→	→	→
Celogen AZ	2.0	4.0	6.0	8.0	10.0
DiCup(R) 40C	3.0	→	→	→	→
	110.0	112.0	114.0	116.0	118.0

1. Fuse Polyethylene DYNK on a mill at 250°F.

2. Add ingredients in order. Take care to keep temperature at or near 250°F. Sheet off.

3. Calender to about 0.040" with top roll at 260°F., middle roll 250°F., and bottom roll cold.

4. Press pre-cure in a gasketed Chelsea at 4000 psi/20'/325°F. Cool in press to room temperature. Expand in hot air 40'/310°F. for A and B and 20'/310°F. for C, D, and E.

TABLE 15

SERIES 1035, SEMI-RIGID ABS, REINFORCEMENT FOR COUNTER AND TOP CAP

	A	
Paracril OZO	46.3	Part I
Kralastic K-2516	53.7	
Polygard	1.0	
Vanstay L	0.6	
" HT	0.4	
" S	0.2	
Plasticizer L-727	7.0	
Stearic Acid	1.0	
	110.2	
Part I	110.20	Part II
Celogen AZ	3.50	
Sulfur	0.75	
Zinc Oxide	5.00	
MBTS	1.00	
Monex(R)	0.40	
	120.85	

1. With cooling water off and a speed of about 30 RPM, Banbury mix Part I as follows:

   0' Load Paracril OZO
   1' Add Kralastic K-2516.
   5' Batch should attain 280 - 300°F.
   Add Stearic Acid, Polygard, and the Vanstays.
   8' Add 1/2 of DOP (Plasticizer L-727)
   10' Add remainder of DOP.
   12' Unload. Complete.
   Turn cooling water on or reduce speed to maintain temperature below 360°F. Sheet off 1/8" thick and cool.

TABLE 15 (Cont'd)

2. Band Part I on a 140°F. or below mill. Blend in Part II ingredients in order. Sheet off 1/8" thick.

3. Calender with top roll at 270°F., middle roll 250 - 260°F., and bottom roll cold.

4. Press pre-cure in a gasketed Chelsea at 4000 psi/15'/300°F. Cool in press. Expand 30'/340°F.

TABLE 16

SERIES 1034, RIGID ABS, REINFORCEMENT FOR COUNTER AND TOE CAP

	A	
Kralastic K-2538	90.0	Part I
Paracril OZO	10.0	Part I
Polygard(R)	0.5	Part I
Ferro 12-V-5	0.1	Part I
Zinc Oxide	1.5	Part I
Diphenyl Phthalate (DPP)	2.5	Part I
	104.6	Part I
Part I	107.2	Part II
Hycar(R) 1312	2.0	Part II
Diphenyl Phthalate (DPP)	2.5	Part II
Celogen AZ	2.0	Part II
	113.7	Part II

1. Starting with a Banbury temperature of 160°F. and RPM of about 30, Banbury mix Part I as follows:

   0' Load Paracril OZO and 1/2 K-2538.
   1' Add Polygard, 12-V-5, Zinc Oxide, DPP, and balance of K-2538. Raise and lower ram. When stock "takes hold", apply full ram pressure. When stock temperature reaches 275°F., turn on cooling water.
   10' Unload (or when temperature is 325 - 340°F. range). Sheet off on a 200°F. mill 1/8" thick.

2. Band Part I on a 160°F. mill. Do not allow mill temperature to exceed 200°F. Add Hycar and DPP slowly and blend in. Add Celogen AZ to blend in. Sheet off and cool.

3. Calender with top roll 270°F., middle roll 250 - 260°F., and bottom roll cold.

4. Press pre-cure in a gasketed Chelsea at 4000 psi/30'/300°F. Cool in press. Expand 40'/300°F.

TABLE 17

POLYURETHANE IMPREGNATION FORMULAS, COUNTER AND TOE CAP

POLYESTER

MATERIAL	PARTS	TEMPERATURE °F.	MIXING TIME
Vibrathane 6004	100	150	1 Minute
MOCA	11	250 (Melted)	
	111		

1. Cure at room temperature for 16 hours.

POLYETHER

MATERIAL	PARTS	TEMPERATURE °F.	MIXING TIME
Adiprene L100	100	150	1 Minute
MOCA	11	250 (Melted)	
	111		

1. Cure at room temperature 16 - 24 hours.

TABLE 18

908, POLYETHER POLYURETHANE FILM,

EXTERIOR COATING FOR BOOT UPPER

PART A

MATERIAL	PARTS
Vibrathane B602	100.0
Ferro V780 Black	2.0
Methyl Ethyl Ketone	100.0
	202.0

PART B

MATERIAL	PARTS
Methylene Dianiline (MDA)	10.0
Methyl Ethyl Ketone	90.0
	100.0

1. Using a two component mixing sprayer, spray and mix Part A with Part B such that the mole ratio of MDA to B602 is 0.85.

2. Cure film 16 hours at 160°F.

TABLE 19

913, POLYESTER POLYURETHANE FILM,

EXTERIOR COATING FOR BOOT UPPER

PART A

MATERIAL	PARTS
Vibrathane 6004	100.0
Ferro V-780 Black	2.0
CB-75 (Trifunctional Isocyanate)	2.0
UV-24	2.0
Methyl Ethyl Ketone	100.0
	206.0

PART B

MATERIAL	PARTS
Methylene Dianiline (MDA)	10.0
Methyl Ethyl Ketone	90.0
	100.0

1. Using a two component mixing sprayer, spray and mix Part A with Part B such that the mole ratio of MDA to 6004 is 0.85.

2. Cure film 16 hours at 160°F.

TABLE 20

SERIES 1025, IIR BUTYL,

EXTERIOR COATING FOR BOOT UPPER

	A	B		
Butyl 325	100.0	100.0	Part I	0'
Antioxidant 2246	1.0	1.0		½'
HAF Black	50.0	50.0		2'
Zinc Oxide	5.0	5.0		3'
Stearic Acid	1.0	1.0		3'
Polyethylene DYLT	3.0	3.0		3'
	160.0	160.0	Dump	8'
Part I	160.0	160.0	Part II	
Sulfur	0.5	-		
Tellurac(R)	3.0	-		
MBTS	1.0	-		
Sulfasan R	-	2.0		
Tuex	-	2.0		
	164.5	164.0		

1. Banbury mix Part I masterbatch as indicated keeping temperature at 300 - 325°F. Sheet off 4 times through a tight mill.

2. Mill mix Part II on a cool (150°F.) mill.

3. Calender with top roll 160 - 170°F., middle roll 130 - 150°F., and bottom roll ice cold.

4. Cure 30'/320°F.

TABLE 21

SERIES 1027, EPDM ROYALENE, EXTERIOR COATING FOR BOOT UPPER

	A	B		
Royalene X301	100.0	-		0'
" X400	-	200.0		0'
Agerite Resin D	1.0	1.0		1'
Zinc Oxide	5.0	5.0		1'
FEF Black	40.0	100.0	Part I	2'
MT Black	-	200.0		3'
Shellflex 790	15.0	-		2'
Circosol 596	-	30.0		3'
Stearic Acid	1.0	1.0		2'
	162.0	537.0	Dump	10'
Part I	162.0	537.0		
MBT	1.0	1.0		
Monex	0.5	0.5		
Ethazate	0.5	0.5	Part II	
Butazate	0.5	0.5		
Arazate	0.5	0.5		
Sulfur	1.0	2.0		
	166.0	542.0		

1. Banbury mix Part I using the indicated times. Keep temperature about 250°F. Sheet off 4 times through a tight mill.

2. Mill mix Part II. Keep temperature 150 - 200°F.

3. Calender with top roll 200°F., middle roll 190°F., and bottom roll cold.

4. Cure 30'/340°F.

TABLE 22

SERIES 1028, CSM HYPALON

EXTERIOR COATING FOR BOOT UPPER

	A	B
Polyethylene DYLT	3.0	-
Hypalon 40	100.0	100.0
Sublimed Litharge	25.0	25.0
Suprex(R) Clay	10.0	-
MT Black	20.0	40.0
Sundex 53	25.0	20.0
NBC	0.5	0.5
MBTS	0.5	0.5
Tetrone A	2.0	2.0
	186.0	188.0

1. Band polyethylene on mill. Add Hypalon reducing mill temperature as Hypalon is added until mill is 100 - 160°F.

2. With mill at 100 - 160°F., add remaining ingredients in order. Mix at least 10 minutes after all ingredients appear dispersed.

3. Calender with top roll 200 - 220°F., middle roll 180 - 200°F., and bottom roll cold.

4. Cure 30'/320°F.

TABLE 23

SERIES 1029, IM VISTANEX,

EXTERIOR COATING FOR BOOT UPPER

	A	B	
Vistanex L-200	100.0	100.0	0'
Agerite Stalite	1.0	1.0	0'
MT Black	90.0	90.0	0'
Polyethylene DYLT	-	25.0	0'
	191.0	216.0	10' Dump

1. Banbury mix using indicated times keeping temperature at 290 - 300 °F. Sheet out 4 times through a tight mill.

NOTE: Series abandoned.

TABLE 24

SERIES 1039, CR NEOPRENE,

EXTERIOR COATING FOR BOOT UPPER

	A	B
Polyethylene 617	4.0	4.0
Neoprene W	100.0	100.0
Neozone D	2.0	2.0
Magnesia BLC	4.0	4.0
Stearic Acid	0.5	0.5
Zinc Oxide	5.0	5.0
SRF Black	20.0	30.0
Sundex 790	10.0	-
Circosol 2XH	-	20.0
NA 22	1.0	1.0
Thiuram A	1.0	1.0
	147.5	167.5

1. Band polyethylene on mill and add Neoprene. Cool rolls to about 100 - 125°F. Add remaining ingredients. Mix at least 10 minutes after materials appear dispersed.

2. Calender with top roll 110 - 120°F., middle roll 100 - 110°F., and bottom roll cold.

3. Cure 30'/310°F.

TABLE 25

SERIES 1048, CR NEOPRENE

EXTRA FIRM FOR SOLING

	A	B	C	D	E	F
Polyethylene DYNK	12.5	25.0	12.5	25.0	12.5	25.0
Neoprene W	100.0	→	→	→	→	→
Neozone D	2.0	→	→	→	→	→
BLC Magnesia	4.0	→	→	→	→	→
SRF Black	42.5	→	→	→	→	→
Stearic Acid	0.5	→	→	→	→	→
Zinc Oxide	5.0	→	→	→	→	→
Celogen AZ	4.0	4.0	7.0	7.0	15.0	15.0
Thionex	1.0	→	→	→	→	→
DOTG	1.0	→	→	→	→	→
Sulfur	1.0	→	→	→	→	→
Retarder W	1.0	→	→	→	→	→
	174.5	187.0	177.5	190.0	185.5	198.0

1. Band polyethylene on the mill and add Neoprene. When the Neoprene is all added, start adding other ingredients and reducing temperature so that Celogen AZ, Thionex, DOTG, sulfur and Retarder W are added at about 160°F. Mill at least 10 minutes after all ingredients appear dispersed. Slab off and cool.

2. Mill to thickness necessary for Chelsea frame.

3. Press pre-cure in a gasketed Chelsea at 4000 psi/18'/300°F. Cool in press. Expand 15'/340°F.

TABLE 26

INITIAL SCREENING

OUTSOLES

	Formula Number	C Number	Water Absorption Lbs./Sq. Ft. Cut Surface	Water Absorption Weight % Change	Density Lbs./Cu. Ft.	Cold Crack
Royalene EPDM	C-260-V6	6427	0.0094	1.3	24.4	OK
Neoprene CR	1021A	6285	0.0384	1.4	33.2	OK
	1021B	6286	0.0379	2.3	19.7	OK
Paracril NBR	1016A	5975	0.0370	1.7	28.0	OK
	1016B	5976	0.0344	2.0	20.4	OK
Butyl IIR	1013A	6277	0.0087	0.8	13.1	OK
	1013B	6278	0.0058	0.4	17.0	OK
Hypalon CSM	1032E	6588	0.0143	0.8	21.0	OK
	1032A	6589	0.0109	0.9	15.3	OK
PVC/NBR	1005A	5799	0.0244	2.3	12.5	OK
Polyethylene	1023A	6472	0.0017	0.1	15.5	OK
Polyurethane	726C	5562	0.0787	3.7	25.6	OK

TABLE 27

INITIAL SCREENING

MIDSOLES & INSOLES

	Formula Number	C Number	Water Absorption Lbs./Sq. Ft. Cut Surface	Water Absorption Weight % Change	Density Lbs./Cu. Ft.	Cold Crack
Royalene EPDM	C-260-U6	6426	0.0105	5.2	8.7	OK
Neoprene CR	1021C	6369	0.033	3.1	12.6	OK
	1021D	6370	0.034	4.7	8.9	OK
Paracril NBR	1016C	5977	0.0308	2.6	14.2	OK
	1016D	5978	0.0306	3.6	10.2	OK
Butyl IIR	1013C	6279	0.0087	1.4	7.5	OK
	1013D	6280	0.0318	0.6	10.8	OK
Hypalon CSM	1032B	6590	0.0096	0.9	12.8	OK
	1032C	6591	0.0096	1.1	10.6	OK
PVC/NBR	1005B	5804	0.0205	2.7	9.0	OK
Polyethylene	1023B	6473	0.0026	0.4	8.7	OK
	1023C	6474	0.0024	0.5	5.7	OK
Polyurethane	93A	6284	1.8081	163.6	13.3	OK

TABLE 28

INITIAL SCREENING

SHANK SUPPORTS

	C Number	Thickness Inches	Flex Test Flexural Modulus Psi	Weight Per Unit Area Gms./Sq. In.
Stainless Steel Type 304	6479	0.063	13,925,800	7.92
	6480	0.092	9,993,600	11.61
Aluminum Type 6061-T6	6477	0.065	9,636,100	2.88
	6478	0.091	7,356,400	4.07
ABS				
MV	6893	0.062	267,800	1.02
MV	6894	0.095	217,700	1.57
SRA	6895	0.064	367,000	1.10
SRA	6896	0.097	277,100	1.66
Acetal	6465	0.077	480,400	1.68
Nylon	6463	0.073	124,300	1.16
	6179	0.096	224,400	1.75
Polycarbonate	6005	0.096	239,100	1.86
	6006	0.060	276,500	1.17

TABLE 29

INITIAL SCREENING

REINFORCEMENTS FOR COUNTER AND TOE CAP

	Material	Urethane	C No.	Dir.	Modulus of Stiffness, Psi x 10^{-3} -20°F.	-10	0	25	50	75 Air	75 Oil
Semi-Rigid	ABS 1035A	-	6706	-	25	17	11	7	8	5	6
Rigid	ABS 1034A	-	6610	-	36	36	33	21	26	28	33
Woven Nylon	3-5376	Ether	6205	Warp	137	54	44	36		13	9
	"	"	"	Fill	175	65	52	28		12	8
	"	Ester	6212	W	55	45	33	30		28	19
	"	"	"	F	75	47	34	34		25	25
Woven Dacron	EXPFV1587	Ether	6206	W	101	66	74	12		14	9
	"	"	"	F	92	66	51	10		9	6
	FV2994	"	6208	W	134	90	73	45		12	9
	"	"	"	F	94	85	55	33		18	13
	EXPFV1587	Ester	6213	W	64	46	36	11		11	6
	"	"	"	F	58	39	33	8		9	5
	FV2994	"	6215	W	93	82	51	19		23	11
	"	"	"	F	120	135	63	19		25	9
Woven Glass	3-5011	Ether	6207	W	95	105	77	49		32	35
	"	"	"	F	299	137	113	65		36	49
	"	Ester	6214	W	130	61	53	20		39	15
	"	"	"	F	91	60	47	17		37	14
Non-Woven Nylon	SAN3500-RC1131	Ether	6202	W	66	55	24	15		5	2
	"	"	"	F	90	69	24	16		5	3
	"	Ester	6209	W	40	19	22	15		10	12
	"	"	"	F	52	20	21	18		13	12

TABLE 29 (Cont'd.)

	Material	Urethane	C No.	Dir.	Modulus of Stiffness, Psi x 10^{-3} -20°F.	-10	0	25	50	75 Air	75 Oil
Non-Woven Dacron	SAN3500-RC1252	Ether	6203	W	88	36	29	17		10	6
	"	"	"	F	81	42	36	16		7	5
	"	Ester	6210	W	40	35	26	19		17	12
	"	"	"	F	26	30	23	17		13	10
Non-Woven Glass	SP803	Ether	6572	W	147	123	111	65	23	23	25
	"	"	"	F	133	117	84	34	24	16	23
	"	Ester	6573	W	93	62	47	45	28	41	32
	"	"	"	F	98	57	56	41	38	39	30
Lantuck	3-9027-01	Ether	6204	W	70	61	60	38		15	19
	"	"	"	F	62	63	63	34		17	24
	"	Ester	6211	W	34	43	27	27		18	20
	"	"	"	F	36	44	30	28		22	20

TABLE 30
INITIAL SCREENING
REINFORCEMENT FOR VAMP

	Material	C Number	Direction	Weight Oz./Sq. Yd.	Tongue Tear Lbs. Pull Ave.	Low	High
Knit Nylon	R5048	6603	Warp	5.1		4.5	11.7
		"	Fill			3.0	12.0
Knit Dacron	6440	8070		3.7	6.6		
	6540	8071		5.0	9.2		
Woven Nylon	3.5310	5534	Warp	3.3		15.0	36.0
	"	"	Fill			20.0	35.0
	3.5326	5535	Warp	5.6	78.0		
	"	"	Fill		85.0		
Woven Dacron	3.5440	5536	Warp	4.5		10.0	49.5
	"	"	Fill			12.5	44.8
	S/3582	5537	Warp	2.4		2.5	3.0
	"	"	Fill			2.5	3.0
	S/FV3796	5538	Warp	3.3		3.3	14.3
	"	"	Fill			3.0	14.3
	15035	6911		4.5	16.8		
	15302	6912		1.4	1.5		
	15205	6913		3.3	19.7		

TABLE 31

INITIAL SCREENING

LINER

	Material	C Number	Weight Oz./Sq. Yd.	Water Absorption Weight % Gain	Tongue Tear Lbs. Pull
Plain Woven Nylon	3.5310	5539	3.3	31.7	41.0
	3.5343	5540	2.0	24.3	6.7
	S/3465	5542	2.0	27.8	4.7
	S/3529	5544	1.8	25.0	8.2
Twill Woven Nylon	S/9029	5545	1.5	16.5	9.1
	P9483	6390	3.0	27.5	14.2
Plain Woven Dacron	S/3458	5541	1.2	12.7	1.9
	S/3471	5543	1.7	23.7	3.5
	3584	6600	1.8	12.1	1.2
	81450	6601	4.4	19.9	16.5
	81719	6602	4.3	19.3	33.7
	15035	6911	4.5	16.3	16.8
	15302	6912	1.4	8.8	1.5
	15205	6913	3.3	16.2	19.7
Twill Woven Dacron					

TABLE 32

INITIAL SCREENING

EXTERIOR COATING

	Formula Number	C Number	Ultraviolet Resistance Weather	Ultraviolet Resistance Fade	Ozone	Water Absorption % Gain	Cold Crack	Abrasion Resistance*
Butyl IIR	1025A	6890	Sl. Dull	0,0,+2	Loop 1-60 0-40	0.07	OK	0.0043
	1025B	8124		0,0,+1	NC	0.13	OK	0.0013
Royalene EPDM	1027A	6627	NC	0,0,-1	NC	1.45	OK	0.0591
	1027B	6628	NC	0,0,-1	NC	1.54	OK	0.2776
Hypalon CSM	1028A	6891	Sl. Dull	0,0,+1	NC	0.17	OK	0.0291
	1028B	6892	Sl. Dull	0,0,+1	NC	0.11	OK	0.0358
Vistanex IM	Could not be made satisfactorily.							
Neoprene CR	1039A	6909	Sl. Dull	0,0,-4	NC	1.16	OK	0.0780
	1039B	6910	Sl. Dull	0,0,-4	NC	1.27	OK	
Polyurethane	908 Ether	6393	Sl. Dull	V.Sl.S.C., Sl.,-3	NC	1.71	OK	0.1160 0.0037
	913 Ester	6394	NC	0,0,-1	NC	1.36	OK	0.0037

*CS17 Wheel, 1000 Gm. Load, 5000 Cycle, Wt. Loss per 1000 Cycles

NC = No Change

TABLE 33

INITIAL SCREENING

INSULATION

	Formula Number	C Number	Compression Set, %*	Density Lbs./ Cu. Ft.	Cold Crack	Water Absorption Lbs./Sq. Ft. Cut Surface	Water Absorption Weight % Change
Royalene EPDM	C-260-H6	6245	22.0	5.5	OK	0.0268	5.9
Neoprene CR	1021E	6371	21.8	6.1	OK	0.0353	7.1
	1021F	6372	11.7	6.5	OK	0.0362	6.7
Paracril NBR	1016E	5987	27.2	7.4	OK	0.0287	4.7
	1016F	5988	26.3	6.8	OK	0.0293	5.2
Butyl IIR	1013E	6281	32.7	7.6	OK	0.0109	1.7
Hypalon CSM	1032D	6579	16.8	10.2	OK	0.0063	0.8
	1032F	6580	18.4	8.0	OK	0.0115	1.7
Polyethylene	1023D	6470	19.7	3.7	OK	0.0025	0.8
	1023E	6471	16.9	3.1	OK	0.0031	1.2
Polyurethane	1.5 #/Cu. Ft.	5985	2.8	1.9	OK	-	-
	3 #/Cu. Ft.	5986	4.4	2.7	OK	-	-
PVC/NBR	1005C	5789	16.6	5.7	OK	0.0421	8.9

*Comp. 25%, Based on Comp. Ht., 24 Hr. Recovery

TABLE 34

SECOND SCREENING

OUTSOLES

	Formula Number	C Number	Fadeometer	Weather-ometer	Comp. Set, %*	Compression Deflection (25%) -20°F.	-10	0 (PSI)	25	50	75°F.
Royalene EPDM	C-260-V6	6940	0,-1,V.Sl. Light	NC	8.1	170	109	71	45	54	55
Neoprene CR	1021A	7662	0,-1,V.Sl. Light	Sl. Dull	3.7	28	27	25	22	20	22
	1021B	6937	0,-2,V.Sl. Light	Sl. Dull	9.4	11	9	9	9	8	8
Hypalon CSM	1032E	6939	Sus. Check, -2,V.Sl. Dark	Sl. Dull	9.9	107	61	28	15	15	13
	1032A	6938	0,+, V.Sl. Dark	Sl. Dull	8.5	90	25	16	9	8	8
Polyurethane	1011	7663	0,-4,Sl. Light	NC	10.3	197	207	175	126	107	96

NC = No Change

*Compression 25%, based on Comp. Ht., 24 Hr. Recovery

TABLE 35

SECOND SCREENING

MIDSOLES AND INSOLES

	Formula Number	C Number	Compression Set, %*	Compression Deflection (25%) (PSI) -20°F.	-10	0°	25	50	75°F.
Royalene EPDM	C-260-U6	6936	10.9	-**	11.0	10.0	9.0	8.0	8.0
Neoprene CR	1021C	6933	8.4	6.6	6.6	6.2	5.6	5.4	6.3
	1021D	6934	21.9	6.4	6.8	5.7	4.4	4.4	4.7
Hypalon CSM	1032B	7124	18.4						
	1032C	6935	10.3	41.0	17.0	8.0	7.0	6.0	6.0

*Compression 25%, Based on Compressed Height, 24 Hour Recovery.

**Beyond capacity of C Cell.

TABLE 36

SECOND SCREENING

REINFORCEMENTS FOR COUNTER AND TOE CAP

	Formula Number	C Number	Density Lbs./Cu. Ft.	Water Absorption Lbs./Sq.Ft. Of Cut Surface
Rigid ABS	1034A	7141	26.0*	0.0330
Semi-Rigid ABS	1035A	7142	26.2*	0.0340
Lantuck Polyester Polyurethane		7143	69.2	0.4080

*NOTE: Subsequent experiments with these compounds produced samples with lower densities (see Table 43). The higher values reported above were caused by expansion at temperatures lower than optimum.

TABLE 37

SECOND SCREENING

REINFORCEMENT FOR VAMP

	Material	C Number	Water Absorption % Gain
Knit Dacron	6440	8070	68.4
	6540	8071	49.1
Plain Woven Nylon	3.5310	7742	31.7
Plain Woven Dacron	81719	7743	19.3
	15205	7744	16.2

TABLE 38

SECOND SCREENING

LINER

	Material	C Number	Ozone	Taber Abrasion Cycles To Failure
Plain Woven Nylon	3.5310	7742	No Change	357
Plain Woven Dacron	81719	7743	No Change	325
	15205	7744	No Change	576

TABLE 39

SECOND SCREENING

EXTERIOR COATING

	Formula Number	C Number	Tensile Psi	Elongation, %	Tear (Psi) Die C	Tear (Psi) Die B
Butyl IIR	1025A	8110	2125	536	144	235
	1025B	8124	2185	613	194	350
Royalene EPDM	1027A	6995	2336	502	144	154
	1027B	6996	1373	292	92	186
Hypalon CSM	1028A	8015	2913	443	62	187
	1028B	8016	2710	383	69	198
Neoprene CR	1039A	8415	2460	610	156	156
	1039B	8416	2254	562	107	146
Polyurethane	908 Ether	6997	4621	489	188	146
	913 Ester	6998	6882	541	244	155

TABLE 40

SECOND SCREENING

INSULATION

	Formula Number	C Number	Flex Test 1,000,000 Cycles	Compression Deflection (25%)					
				-20° F.	-10° F.	0°F. (PSI)	25° F.	50° F.	75° F.
Royalene EPDM	C-260-H6	6932	OK	8.5	7.0	6.8	5.9	5.0	4.7
Neoprene CR	1021E	6929	OK	8.6	6.2	6.8	5.3	6.0	4.8
	1021F	6930	OK	3.5	3.2	3.3	2.9	3.2	2.9
Hypalon CSM	1032	6931	OK	18.0	10.7	6.8	5.3	4.7	4.6
Polyethylene	1023D	6927	OK	24.9	22.6	20.8	15.5	12.6	10.5
	1023E	6928	OK	22.4	19.8	17.3	13.8	10.7	9.7
Polyurethane	1.5 #/$Ft.^3$	6925	OK	0.6	0.6	0.6	0.6	0.5	0.5
	3#/$Ft.^3$	6926	OK	1.6	1.1	1.1	0.8	0.8	0.8
PVC/NBR	1005C	8009	OK	10.6	7.7	6.7	4.9	4.1	3.7
	1005D	8010	OK	7.7	5.5	4.8	3.7	3.2	3.0

TABLE 41

FINAL SCREENING

OUTSOLES

	Formula Number	C Number	Oil Resistance	Abrasion Resistance*	Thermal Conductivity BTU-In./Hr./Ft.^{2}/°F.
Royalene EPDM	C-260-V6	7732	Sl. Vol. Change and Shrinkage	0.2238	0.606
Neoprene CR	1021A	7863	No Change	0.0830	0.774
	1021B	7864	No Change	0.1820	0.704
Hypalon CSM	1032E	7931	No Change	0.1574	0.484
	1032A	7932	No Change	0.3640	0.387
Polyurethane	1012	7734	No Change	0.0333	0.430
		8435			

*Taber H18 Wheel, 1000 Gm. Load, 300 Cycles, Grams Lost

TABLE 42

FINAL SCREENING

MIDSOLES AND INSOLES

	Formula Number	C Number	Abrasion Resistance*	Thermal Conductivity BTU-In./Hr./Ft.^{2}/°F.
Royalene EPDM	C-260-U6	7733	0.2973	0.324
Neoprene CR	1021C	7866	0.6609	0.387
	1021D	7867	0.3200	0.298
Hypalon CSM	1032B	7928	1.0518	0.287
	1032C	7929	1.3415	0.276
	1032D	7930		0.387

*Taber H18 Wheel, 1000 Gm. Load, 300 Cycles, Grams Lost

TABLE 43

FINAL SCREENING

REINFORCEMENTS FOR COUNTER AND TOE CAP

	Formula Number	C Number	Density Lbs./Cu. Ft.	Thermal Conductivity BTU-In./Hr./Ft.^{2}/^{o}F.
Rigid ABS	1034A	7714	12.9	0.346
Semi-Rigid ABS	1035A	7715A	16.1	0.365
Lantuck Polyester Polyurethane		7715B	63.4	1.07

TABLE 44

FINAL SCREENING

REINFORCEMENT FOR VAMP

	Material	C Number	Weight/Area Oz./Sq. Yd.	Grab Tensile Lbs. Pull	Elonga-tion %	Taber Abrasion Cycles To Failure
Knit Dacron	6440	8070	3.7	27	60.8	473
	6540	8071	5.0	39	64.8	684
Plain Woven Nylon	3.5310	7742	3.3	98	18.8	357
Plain Woven Dacron	81719	7743	4.3	145	12.0	325
	15205	7744	3.3	123	12.0	576

TABLE 45

FINAL SCREENING

LINER

	Material	C Number	Weight/Area Oz./Sq. Yd.	Grab Tensile Lbs. Pull	Elongation %	Ozone Resistance
Plain Woven Nylon	3.5310	7742	3.2	98	18.8	No Change
Plain Woven Dacron	81719	7743	4.2	145	12.0	No Change
	15205	7744	3.2	123	12.0	No Change

TABLE 46

FINAL SCREENING

EXTERIOR COATING

	Formula No.	C No.	Thickness Inches	Weight/Area Oz./Sq. Yd.	Flex Test	Oil Resistance
Butyl IIR	1025A	8110	0.042	34.5	0-100 at 1,000,000 Flexes.	Sl. Swell
	1025B	8124	0.039	32.8	Cracked 396,434 Flexes.	Sl. Swell
Royalene EPDM	1027A	7737	--	32.7	9-30 and 0-70 at 633,756 Flexes.	Sl. Swell
	1027B	7738	--	27.7	0-100 at 1,215,535 Flexes.	Sl. Swell
Hypalon CSM	1028A	8015	0.036	33.2		Sl. Swell
	1028B	8016	0.036	38.1		Sl. Swell
Neoprene CR	1039A	7735	--	40.0	0-100 at 1,215,535 Flexes.	Sl. Swell
	1039B	7736	--	41.2	0-100 at 1,215,535 Flexes.	Sl. Swell
Polyurethane	908 Ether	7739	--	9.7	0-100 at 1,215,535 Flexes.	No Change
	913 Ester	7740	--	8.6	0-100 at 1,215,535 Flexes.	No Change

TABLE 46 (Cont'd.)

Formula No.	Oz./Sq. Yd. Calculated From Calculated Specific Gravities
1025A	24.2 at 0.025 in. thick
1025B	24.0 " " " "
1027A	19.3 at 0.025 in. thick
1027B	23.6 " " " "
1028A	26.2 at 0.025 in. thick
1028B	26.4 " " " "
1039A	24.7 at 0.025 in. thick
908	13.5 at 0.015 in. thick
913	13.5 " " " "

TABLE 47

FINAL SCREENING

INSULATION

	Formula No.	C No.	Density Lbs./Cu. Ft.	Tensile PSI	Elongation %	Tear Lbs. Pull	Thermal Conductivity BTU-In./Hr./Ft.^{2}/°F.
Royalene EPDM	C-260-H6	7730	4.9	50.5	256	9.2	*0.423
Neoprene CR	1021E	7866	7.1	35.8	138	4.1	*0.276
	1021F	7869	5.5	70.7	167	9.3	*0.235
Polyethylene	1023D	7882	3.8	115.0	170	14.4	*0.352
	1023E	7883	3.2	80.0	158	12.4	*0.352
Polyurethane	1.5# Cu.Ft.	7717		14.8	227	2.1	
	3# Cu.Ft.	7718		15.9	259	3.0	
PVC/NBR	1005C	8009	8.0	72.2	338	9.7	*0.387
	1005D	8010	5.6	54.4	322	7.8	*0.221

*NOTE: Rechecked values for thermal conductivity.

TABLE 48

EXTRA TESTS

INSULATION

	Formula No.	C No.	Thermal Conductivity BTU-In./Hr./Ft.^{2}/^{o}F.	Compression Sets % change based on compressed heights. 24 Hour Recovery: Compressed 25% Room Temp.	Compressed 25% 22 Hrs. 158^{o}F.	Compressed 50% Room Temp.	Compressed 50% 22 Hrs. 158^{o}F.
PVC/NBR	1005D	8631	0.235	-	-	-	-
	1005D	8636	-	25.9	89.9	38.7	87.2
Neoprene CR	1021F	8632	0.242	-	-	-	-
	1021F	8637	-	18.4	83.3	37.6	83.0
Polyethylene	1023D	8633	0.337	-	-	-	-
	1023E	8638	-	8.3	92.4	13.8	94.2
Royalene EPDM	C-260-H6	8634	0.323	-	-	-	-
	C-260-H6	8639	-	8.6	98.7	23.7	95.5
Polyurethane	1.5# Cu. Ft.	8635	0.298	-	-	-	-
Open Cell Foam	1.5# Cu. Ft.	8640	-	1.9	8.4	1.0	3.5

TABLE 49

FIRM NEOPRENE SAMPLES FOR SOLING

Formula No.	C No.	Density Lbs./Cu. Ft.	Taber Abrasion H18 Wheel, 1000 Gm. Load, 300 Cycles, Grams Wt. Loss	Compression Deflection 25% (PSI) -20°F.	-10	0	25	50	75°F.
1048A	131	45.7	0.1119	293	207	217	159	161	132
1048C	132	23.8	0.0988	156	119	105	79	73	49
1048E	133	6.6	0.8130	17	16	16	14	14	12

Formula No.	C No.	Compression Set % Change 24 Hr. Recovery Based on Comp. Ht.	Oil Resistance	Water Absorption Lbs./Sq.Ft. Of Cut Surface	Thermal Conductivity - BTU - In./Hr./Ft.^{2}/°F.
1048A	131	9.4	No Change	0.02566	0.645
1048C	132	10.2	No Change	0.02732	0.516
1048E	133	19.7	No Change	0.03872	0.337

TABLE 50

HUMIDITY TESTS ON POLYURETHANES

TWO WEEKS AT 170°F. AND 100% RELATIVE HUMIDITY

	Tensile PSI	Elongation %	Taber Abrasion, CS17 Wheel, 1000 Gm. Load 5000 Cycles, Wt. Loss Per 1000 Cycles Gms.
Polyether Exterior 908 (C# 7925)	2429	520	0.0044
Original	4621	489	0.0037
Polyester Exterior 913 (C# 7926)	2374	639	0.0062
Original	6882	541	0.0037
Polyether Outsole 1012 (C# 7927)	213	146	*0.2780
Original	-	-	*0.0333

*Grams weight lost for 300 cycles = 30% x 0.2780 = 0.0834 for comparison with outsole original test which was run 300 cycles at 1000 gm. load with H18 wheel and total grams of weight loss reported.

TABLE 51

180° FOLD TEST RESULTS

	Formula No.	% Recovery After 180°F. Folding: 2 Weeks at Room Temperature — Rec. After 1 Hour	2 Weeks at Room Temperature — Rec. After 1 Week	22 Hrs. at 158°F. — Rec. After 1 Hour	22 Hrs. at 158°F. — Rec. After 1 Week
Uncovered Cellular Insulation					
Neoprene	1021F	nil	65	-	-
PVC/NBR	1005D	nil	65	-	-
Open Cell Urethane Foam	1.5# Cu. Ft.	100	100	-	-
Polyethylene	1023E	25	80	-	-
Royalene	C-260-H6	45	95	-	-
15205 Dacron One Side and 908 Polyurethane Film on Other Side of Insulation					
Neoprene	1021F	20	35	10	10
PVC/NBR	1005D	15	30	10	20
Open Cell Urethane Foam	1.5# Cu. Ft.	nil	35	nil	15
Polyethylene	1023E	25	55	10	20
Royalene	C-260-H6	30	40	10	15
Liner and Exterior Bach Alone					
15205 Dacron	-	Creased	Creased	Creased	Creased
3.5310 Nylon	-	Creased	Creased	Creased	Creased
Polyurethane Film	908	100	100	100	100
Polyurethane Film	913	100	100	-	-

TABLE 52

LINER FABRIC TESTS

	Heiress Style Orlon Knit	3.5336 Nylon Knit
Weight, oz./sq. yd.	4.6	2.3
Tongue Tear, Lbs.	4.2	2.5
Grab Tensile, Lbs.	53.0	32.4
Elongation, %	88.0	420.0
Water Absorption, % Wt. Gain	159.0	160.0
Abrasion Resistance, Cycles To Failure, Taber, CS17 Wheel, 1000 Gm. Load	418.0	100.0

TABLE 53

ADHESIVES TESTS

Abbreviations Used

N	=	Nylon Fabric 3.5310
D	=	Dacron Fabric 15205
EPDM	=	Royalene
U	=	Polyurethane Closed Cell
U(OC)	=	Polyurethane Open Cell Foam
PVC/NBR	=	Polyvinyl Chloride/Acrylonitrile (Paracril)
CR	=	Neoprene
E	=	Polyethylene
CSM	=	Hypalon
RABS	=	Rigid ABS (Acrylonitrile/Butadiene/Styrene Resin)
SRABS	=	Semi-Rigid ABS
SS	=	Stainless Steel
AL	=	Aluminum Alloy
A	=	Acetal
(E)	=	Exterior
U(E)	=	Polyurethane Exterior, Film
CR(E)	=	Neoprene Exterior, Film
IIR(E)	=	Butyl Exterior, Film
AF	=	Adhesive Failure
P	=	Partial Material Failure
C	=	Complete Material Failure

TABLE 53

ADHESIVE TESTS

Material & Adhesive	EPDM	U	PVC/NBR	CR	E	CSM	U(OC)	D	N	RABS
Nylon 3.5310 M6200 Cold	2.5 AF	2.4 AF	1.6 P	1.3 AF	0.1 AF	0.1 AF				
Nylon 3.5310 M6200 Heat	2.4 P	9.1 AF	4.0 P	1.8 AF	0.9 AF					
Dacron 15205 M6200 Cold	1.7 AF	5.0 AF	3.2 P	1.9 AF	0.4 AF	1.4 AF				
Dacron 15205 M6200 Heat	2.4 P	5.3 AF	3.9 C	2.3 AF	1.7 AF					
Dacron 15205 M6230 Heat	2.4 P	6.6 AF	2.8 C	3.9 C	4.9 C					
Nylon 3.5310 M6230 Heat	2.2 P	6.4 AF	3.1 C	4.0 C	5.1 P					
Nylon 3.5310 M5130 Cold	1.9 P	7.9 AF	3.7 C	5.9 C	4.2 P					
Dacron 15205 M6130 Cold	2.1 P	8.1 AF	3.5 C	5.3 C	3.7 P					
Nylon 3.5310 Bostik 1225C	3.0 C	7.5 AF	5.2 C	3.5 C	5.0 P					
Dacron 15205 Bostik 1225C	2.2 C	8.1 AF	3.7 C	4.9 C	4.8 C					

TABLE 53 ADHESIVE TESTS (Cont'd.)

Material & Adhesive	EPDM	U	PVC/NBR	CR	E	CSM	U(OC)	D	N	RABS
U M6200 Heat	1.8 C			2.4 P						
U Bostik 1225C	2.5 C		4.3 C	3.4 C	6.0 C		1.2 C			
SRABS M6200 Cold	1.9 P		3.0 C	2.5 AF	1.2 AF		1.1 C	3.9 AF	1.7 AF	
SRABS M6130 Cold	2.1 C		4.1 C	7.0 P	5.8 C		1.1 C	11.4 AF	12.5 AF	
RABS M6200 Cold	2.5 P		2.3 C	2.4 AF	1.3 AF		1.1 C	0.9 AF	1.5 AF	
RABS M6130 Cold	2.6 P		3.7 C	7.9 P	5.7 P		1.3 C	8.2 AF	9.0 AF	
IIR (E) Bostik 1225C	2.4 C		2.1 AF	2.4 AF	3.4 AF		1.3 AF			
CR(E) Bostik 1225C	2.5 C		3.1 C	5.1 C	2.8 AF		1.1 C			
IIR(E) M6234	0.9 AF		0.4 AF	1.0 AF				1.4 AF	1.2 AF	3.3 AF
CR(E) M6234	0.2 AF		0.1 AF	0.3 AF				0.3 AF	0.4 AF	0.5 AF

TABLE 53 ADHESIVE TESTS (Cont'd.)

Material & Adhesive	EPDM	U	PVC/NBR	CR	E	CSM	U(OC)	D	N	RABS
IIR(E) M6366	3.5 P		2.9 AF	3.1 AF				3.6 AF	3.6 AF	6.9
CR(E) M6366	2.1 P		7.6 P	5.6 P				7.5	7.2	5.0 AF
IIR(E) M6594	1.0 AF		3.2 AF	3.0 AF				3.1 AF	4.3 AF	5.3 AF
CR(E) M6594	1.3 AF		3.5 P	3.1 C				7.2 AF	3.1	6.6 AF
IIR(E) M6300	3.1 AF		2.8 AF	2.6 AF				3.2 AF	3.1 AF	5.6 AF
CR(E) M6300	2.5 C		6.2 P	5.0 P				5.7 AF	6.9	3.1 AF
IIR(E) S5006	3.6 AF		3.5 AF	2.0 AF				3.5 AF	3.7 AF	4.3 AF
CR(E) S5006	2.6 P		5.5 P	3.8 P				6.8 AF	5.5 AF	4.[illegible] AF
IIR(E) S5010	3.5 AF		4.7 AF	3.1 AF				5.6 AF	5.7 AF	8.6 AF
CR(E) S5010	2.2 C		5.0 AF	3.4 AF				5.5 AF	5.3 AF	7.1 AF
IIR(E) S5200	0.9 AF		0.3 AF	0.3 AF				0.6 AF	0.4 AF	0.5 AF

TABLE 53 ADHESIVE TESTS (Cont'd.)

Materials & Adhesive	EPDM	U	PVC/NBR	CR	E	CSM	U(OC)	D	N	RABS
CR(E) S5200	0.4 AF		0.2 AF	0.2 AF				0.3 AF	0.5 AF	0.2 AF
SS M6200 Cold	2.6 P	3.5 AF		3.1 P						
SS M6130 Cold	1.8 C	14.2 AF		6.8 C						
Al M6200 Cold	2.5 P	1.3 AF		0.0 AF						
Al M6130	2.3 C	17.2 AF		6.5 C						
Acetal M6200 Cold	2.5 P	6.5 AF		2.4 AF						
Acetal M6130 Cold	2.0 C	17.0 AF		4.6 C						
SS M6230 Cold	2.5 P	18.2 AF								
Al M6230 Cold	2.3 P	14.1 AF								
Acetal M6230 Cold	2.2 P	14.5 AF								
U(E) Ether M6200 Cold	0.6 AF		2.2 C	3.1 P	0.5 AF		0.7 C			

TABLE 53 ADHESIVE TESTS (Cont'd.)

Material & Adhesive	EPDM	U	PVC/NBR	CR	E	CSM	U(OC)	D	N	RABS
U(E) Ester M6200 Cold	0.3 AF		3.4 P	3.5 P	0.6 AF		0.6 C			
IIR(E) M6200 Cold	1.3 AF		2.5 AF	2.4 AF	1.5 AF		0.9 C			
CSM(E) M6200 Cold	0.0 AF		0.0 AF	0.1 AF	0.1 AF		0.8 C			
CR(E) M6200 Cold	0.6 AF		0.2 AF	0.2 AF	0.2 AF		1.0 C			
U(E) Ether Bostik 1225C	1.0 AF		1.4 AF	0.9 AF	3.6 P		0.3 AF			
U(E) Ester Bostik 1225C	2.6 P		2.7 C	2.1 AF	3.9 P		1.0 AF			

SECTION 2 - FABRICATION STUDIES

Materials Consideration

Certain ground rules were established with the project officer. It was proposed to use a minimum number of components selected from the top candidates evaluated in Section 1.

It was further proposed that fastening and closure devices be kept as simple as possible, if even to be considered at all. It was felt that the major concentration of effort should be placed upon attaining the performance objectives of lightweight, low water absorption, and thermal insulation. The scope of work called for a weight of 15 oz. per boot, a maximum water absorption of 5%, and insulation sufficient for service down to -20°F. for periods of two hours of inactivity.

To aid in accomplishment of these objectives, a basic pull-on type boot was selected as the starting point. Initially only those components which traditionally have been found necessary for assembly of a basic construction were used. It was proposed to use the following components:

Components - Basic Boot

- Fabric Liner
- Inner Counter
- Upper Insulation
- Insole
- Shank Support
- Midsole
- Outsole
- Vamp Cover
- Backstay
- Toe Cap
- Foxing Reinforcement
- Top Bind Reinforcement
- Counter
- Exterior Coating

The objectives of lightweight, low water absorption, and thermal insulation, were dependent on the proper selection of candidate materials from Section 1, coupled with the use of a basic design having the minimum number of components.

The two key areas for potential weight reduction appeared to be in the bottom construction, i.e., insole, midsole, outsole, heel and in the elimination of the numerous layers of rubber coated fabrics used on the standard insulated boot.

The use of a lightweight, cellular outsole and heel, possibly integrally molded, and an exterior upper coating of a high strength material which would be impermeable, was proposed for these areas.

The properties of low water absorption and thermal insulation would be derived through using the best combinations of candidate materials tested in Section 1.

The primary candidates selected from studies conducted in Section 1, in order of preference, were as follows:

Primary Candidates		Density (16/Cu. Ft.)
Upper Insulation		
Polyethylene	1023E	3.1
Neoprene	1021F	6.5
Royalene	C-260-H6	5.5
Toe Cap and Counter Reinforcement		
Rigid ABS	1034A	12.9
Vamp and Liner Fabrics		
Dacron	15205	-
Nylon	3.5310	-
Outsole		
Polyurethane	1012A	24.0
Neoprene	1048C	23.8
Royalene	C-260-V6	24.4

Insole-Midsole		Density (16/Cu. Ft.)
Polyurethane	1012A	24.0
Neoprene	1021C	12.6
Royalene	C-260-U6	8.7
Exterior Coating		
Polyurethane	908	-
Butyl	1025A	-
Neoprene	1039A	-
Shank Support		
Stainless Steel	Type 304	-
Aluminum	Type 6061-T6	-
Adhesives		
M-6230	(Nitrile Base)	
M-6130	(Neoprene Base)	
Bostik 1225-C	(Urethane Base)	
M-6200	(Urethane Base)	

Materials Preparation

Prior to the start of pattern work, it was necessary to estimate the overall thickness required of the various component parts, and provide the pattern maker with the components in those thicknesses.

Using data accumulated during Section 1 studies, relative to the thermal conductivity and weight per unit of area of the various candidate materials, estimates were made of the probable thickness requirements for upper insulation, toe cap and counter, and the various components of the bottom construction, which included insole, midsole and outsole.

The most immediate requirement was to obtain a quantity of upper insulation and toecap and counter material in the estimated thicknesses. These parts would be among the first to be patterned, and their relative position in the construction would have a direct bearing on the ultimate dimensions of parts to be added later on. Accordingly, the prime candidate for each these components, polyethylene 1023E for the upper insulation, and rigid ABS 1034A for toecap and counter, were prepared by splitting the whole stock as received to the proper dimension.

Slab stock of the expanded polyurethane soling compound was made available in the estimated thickness.

No preparation of the lining fabric was required at this point. Reinforcement strips and shank supports were available.

It should be pointed out that only the prime candidate in each component category was made ready for pattern work. Alternate choices were not to be considered unless difficulties arose during the fabrication studies.

Materials available for initial pattern work were as follows:

MATERIALS FOR PATTERNS
WITH ESTIMATED THICKNESSES

Lining Fabric	Dacron 15205	
Upper Insulation	Polyethylene 1023E	.125"
Toe Cap & Counter	ABS 1034A	.125"
Insole-Midsole-Outsole	Polyurethane 1012	.600"
Reinforcement Strips	Polyurethane 908	.015"
Shank Support	Type 304 Stainless Steel	
Adhesive	M-6230	

Description of Prototype Boots

A. Boot #1

A pattern for the leg lining and sock lining was developed to use on the standard U. S. Rubber Company Snugleg last Size 9, 22FF. The prime candidate material #15205 White Dacron was used for the first trial. It was noted that the square weave was not adaptable to a sock construction, so a pattern was made for the leg lining

only. After several trials, it was found that the material would not conform to the contour of the last. Another attempt was made using the second candidate, 3.5310 White Nylon. The same problems existed with this material. A decision was then made to use the prime candidate. A light coating of adhesive was applied to the outside of the material and then the front and back seams were closed using a merrow stitch. The stitched lining was then cemented all around the bottom edge on the face side. The lining was pulled on to the last and a standard type innersole was placed on the bottom and the lining last to it. The top of the lining was then pulled taut and strapped to the last.

Adhesive used in this boot was U. S. Rubber Co. #M6230. Please note that wherever the word adhesive is used in the construction of this boot it refers to the number above.

A coating of adhesive was then brushed on both the front and back seams. A strip of polyurethane 908 about .015 ga., 3/4" wide, was cemented and placed over the seams from the top to the bottom of the boot. Adhesive was then brushed on the area of the top cap and counter. A pattern was made for the toe cap and it was cut out of Rigid ABS #1034A, .030 ga. This part was skived all around, 1/4" wide. Adhesive was applied to the skived side and the toe cap was preheated to a pliable state and placed on the boot turning 1/4" over the bottom edge. After the pattern was made for the counter it was cut and treated in the same manner as the toe cap. The entire surface of the boot was then covered with adhesive.

A two piece insulation pattern was developed and cut from polyethylene #1023, 1/8" in thickness. These parts were skived top and bottom 1/2" wide. A coating of the adhesive was applied to the skived side and placed on the boot with a butt seam both front and back. The insulation covered the entire height of the boot which was 12" inside dimension. Adhesive was applied 1" wide on front and back seams and around the top. Three 3/4" strips of Polyurethane 908 were coated with the adhesive and placed over the front and back seams from the top to the bottom of the boot, and around the top to seal the edges of the insulation. The outsole for this boot was hand made, plying up slabs of urethane stock and using a rib design for the tread.

The outsole component was buffed and coated with adhesive. A coating of adhesive was then brushed all over the bottom of the boot and rolled. A coating of the adhesive was brushed on 1-1/4" wide around the area where the outsole meets the insulation. A 1" strip of polyurethane was cemented and placed around the outsole on the coated area.

B. <u>Boot #2</u>

To efficiently test the thermal qualities of the proposed boot it was necessary to develop a new last to fit the "Copper Foot" at the

Natick Laboratories. This last was developed from the Size 10 specifications of a government last and the leg and ankle measurement was taken from the standard U. S. Rubber 36F last. With this change in last it was necessary to develop new patterns for all the necessary parts. After a discussion of the dimensions of the new boot it was agreed that the inside height would be 9-1/2" high and the insulation would cover an area 6" high, inside measurement.

Two new lining materials were presented for evaluation on this boot. The first was a two way stretch 100% nylon. There was little control over the positioning of the material after it had been placed on the last. The second was a black diving suit material which had the same characteristics as #1. It was decided to make the best boot possible using the 100% stretch nylon, and in the meantime make every effort to find another more suitable material.

The material was treated the same as in Boot #1 and a sock type lining was developed. This constituted a 2-piece leg lining, merrow stitched to the bottom of the lining. Stitching was very difficult due to stretch. This assembly was placed on the last and strapped around the top. The adhesive used in this boot was the same as in Boot #1.

The front and back seams were treated with the adhesive and polyurethane strips 3/4" wide and about .015 ga. were treated in the same manner and placed on the seams from top to bottom. Preparation for applying the toe cap and counter was the same as Boot #1 except that the material was .070 ga. At this point the adhesive was brushed on, over the boot to a height of 6". Then the insulation was cut and treated the same as Boot #1, and applied in the same manner with butt seams front and back. Adhesive was applied to front and back seams and the same type polyurethane strips were placed as in Boot #1. It was noted that a smooth butt joint was difficult to make due to the extreme grab of the adhesive used. It was decided to look at a new approach of the insulation pattern for the next boot.

At this point a new outsole mold was developed to fit the new last. The tread design was taken from the government non-skid concept. After the first outsole had been molded, it was noted that a considerable amount of shrinkage took place in the curing process. A steel shank was embedded in the outsole and this assembly was coated with the adhesive and placed on the boot. The outsole area was treated the same as Boot #1 and a 3/4" strip of polyurethane was used as a foxing. This boot was stripped from the last and exterior coating applied. A great deal of distortion was noted due to shrinkage of the outercoating during the drying process.

C. Boot #3

Due to the unsatisfactory shrinkage condition of Boot #2, another boot was started immediately. By this time another lining material had been received, a 100% orlon knit. It had good body with the right amount of stretch. This was treated the same as the other materials. A sock lining construction was also used on this boot. Adhesive in this boot was USR Co. #6130. Adhesive was applied on seams and 1/2" polyurethane strips were used to cover the front and back seams and a 5/8" strip was used for the top band. The counter and toe cap were created in the usual manner but the gauge was increased to .145", skived 3/8" wide. This thicker cross-section caused some trouble in applying to the boot, but when enough heat was applied it was possible to conform to the last. The boot was then treated with adhesive, the same as Boot #2.

A new concept for the insulation pattern was applied to this boot. In place of the front and back seam butt construction, this boot was made with an overlapping seam. To accomplish this it was necessary to increase amount of material 1/4" on the front and back and then skive 1/2" wide. This was in addition to the skiving of the top and bottom. The outcome of this construction showed the following skiving operation: The insulation part of the left side of the boot is skived 1/2" top and bottom on the back side, and the front and back is skived on the face side. The insulation part of the right side of the boot is skived 1/2" all around on the back side. This means that the left side is treated with adhesive on the back side and placed on the leg of the last. Then the skived edges and front and back are treated with adhesive. The right side is now treated with adhesive and placed on the leg of the last and the front and back seams overlapped. This concept accomplished the following:

1. Easier placement of parts.

2. Feather edge on seams.

3. Eliminated need for some reinforcing strips.

4. Improved adhesion.

5. Complete insulation thickness on seams.

The outsole assembly and treatment on this boot was the same as Boot #2. This boot remained on the last during the spraying of the exterior coating. The boot was stripped after coating had dried and little or no distortion was noted. One observation was made

after stripping. Due to the fact that the outsole mold was made in a flat plane, when the boot was stripped from the last it was noted that the outsole had a tendency to come back to its natural state, that of a flat plane, thus affecting proper tread of the boot bottom.

D. Boot #4

This boot was fabricated the same as Boot #3 except that some of the materials were changed to different thicknesses.

The 100% orlon lining was treated with a urethane solution on both sides. After the drying period it was noted that the material had lost a considerable amount of its stretch and became very boardy. It was also noted after the lining had been stitched together, the thread had a tendency to fracture the material.

After the lining had been placed on the last, it was treated the same as Boot #3, as were the front and back strips, toe cap, counter and top band.

After the first approximate results were received from the Copper foot tests, it was decided to increase the thickness of the polyethylene insulation. In Boot #4 the insulation on the right side gauged an average of .250" in thickness, while the left side averaged .238". The treatment of the insulation was the same as Boot #3.

It was the consensus of all, that the outsole was too heavy in gauge, so it was decided to alter the mold in this respect and at the same time endeavor to lengthen it to accomplish a better fit. The alteration changed the gauge at the Ball area from 1.055 to .725, and 3/16" holes were drilled in the heel portion of the outsole to further reduce the weight. The overall weight reduction of the altered outsole was approximately 55-1/2 grams.

The application and treatment for the outsole and the remainder of the parts was the same as Boot #3.

During the spraying operation it was noted that care should be taken on placing the front and back strips. A small amount of tension should be applied to the strips when placing on the seams to avoid any wrinkling, as the outer coating shrinks in the drying process. This also confirms the fact that the lining must be secured to the last to make sure it is held in position during the fabrication, spraying and drying operations.

E. Boot #5

This boot was requested by Project Officer, Mr. J. E. Assaf of the U. S. Army Natick Laboratories to be used for a walking test in the NLABS climatic chambers. (See Appendix A). Photos of the boot are shown on following pages.

This boot was identical to Boot #4 with the following exceptions:

1. Lining was coated with a light film of urethane on the outside only.

2. Both the right side and the left side of the insulation gauged an average of .253".

F. Boot #6

It was decided that this boot would be the last prototype made under this contract. The boot involved construction changes in the lining and insulation. A new lining material of 100% polypropylene, knit weave with a weight of 3.75 ounces per sq. yd. was made for us by Draper Brothers. A coating of urethane was applied to the outside of this fabric. A new lining pattern was developed omitting the back seam which was prompted by a discussion of the possibilities of seam failures due to abrasion when donning and doffing this type pull-on boot. Therefore, this boot has but one leg seam, that being at the front. The sock lining was made of the same material and merrow stitched to the lining. This assembly was then pulled on to the last and fastened the same way as the other boots.

The counter and toe cap were of the same material and Boot #4 and 5 and also applied in the same manner.

A new concept of applying the insulation to this boot was developed. Two layers of 1/8" polyethylene were placed on this boot in the following manner. The first layer applied had an average thickness of .118. The shape of the pattern, skiving operation and cementing was the same as Boot #4 and 5. This was placed on the cemented lining in the usual manner. A new pattern for the second layer was developed omitting the front seam.

This pattern covered the first layer of insulation approx. 3-1/4" up on the heel area, 4-1/2" on the ankle and 7-1/2" on the vamp taking a contour measurement. This layer averaged .123 gauges in thickness. This was skived 1/2" all around the perimeter on

the back side of the polyethylene with the exception of the left side at the back lap area. This was skived on the Face side. Cement was not applied to the entire 2nd layer. It was applied only to the skived margin. Also the 1st layer was marked with a pencil line to give guidance in cementing the area where the 2nd layer was to be placed. The cement line should be at least 1/2" wide. The remainder of the components, namely, Top Band, Outsole, Steel Shank and Foxing were the same as Boot #5.

During the spraying of the outer coating on this boot, it was observed that the 2nd layer of insulation had a tendency to sag at the vamp area. After the coating had dried it was noted that the sagging had practically disappeared.

Although this experimental boot was assembled within the time limit of the contract, it was not possible to complete an evaluation of its features within the scope of this contract.

COPPER FOOT CALORIMETER DATA

DEVELOPED BY U. S. ARMY NATICK LABORATORIES

Sectional insulating values for experimental Boots #2 and #3 were measured on the sectional Foot Calorimeter* operated at approximately 65°F. For comparison, values were determined for a standard black cold-wet insulated Army boot. Boots were measured in an upright position with the sole resting on an elevated metal plate.

Levels of insulation over the various calorimeter sections, in clo** units, are given for each boot in the table below. These values indicate the contribution of the boundary air layer outside the boot plus that of the wool sock worn on the foot. No values are given for Sections 1 - 13 and 2 - 14 (see below) since these lower leg sections of the Calorimeter were outside the boots.

TABLE FOR COPPER FOOT CALORIMETER DATA

Section	Standard Boot (1,247 Gms.) (44 Oz.)	Boot #2 (490 Gms.) (17.1 Oz.)	Boot #3 (454 Gms.) (16.0 Oz.)	Boot #4 (452 Gms.) (16.0 Oz.)
3 - 15	1.48	1.97	1.80	1.35
4 - 16	1.97	1.65	1.48	1.73
5 - 17	2.18	1.71	1.62	1.82
6 - 18	2.16	1.82	1.79	1.94
7 - 19	1.80	1.62	1.59	1.73
8 - 20	2.49	1.63	1.51	1.86
9 - 21	2.31	1.27	1.21	1.63
10 - 22	1.72	1.37	1.35	1.49
11 - 23	2.55	2.10	2.18	2.02
12 - 24	3.03	2.54	2.60	2.16
Overall (Sect. 3-12)	2.00	1.72	1.66	

It should be noted that the Standard Boot values are for a size 10 XW boot, which was the only size 10 boot available at the time of the study. The Calorimeter is sized to fit a size 10 R boot and was a loose fit for the 10 XW boot. For this reason, values obtained for the standard boot may be high.

* Research Study - Areas of Effective Insulation in Cold Climate Footwear And Development of the Sectionalized Foot Calorimeter, Clothing Branch Series Report No. 16. QMR&E Command, Natick, Mass. 1960.

**Clo: The amount of insulation necessary to maintain in comfort a sitting, resting subject in a normally ventilated room (air movement 20 ft/min) at a temperature of 70°F. and a humidity of air which is less than 50 percent.

The Copper Foot data was used to provide guidelines in determining thermal insulating properties of selected materials and in design construction.

However, readings derived from this test are recorded for the entire zone. This implies that pinholes or leakages through the insulation cannot necessarily be located precisely by this test.

By referring to the figure in this section which shows the shape and location of the test zones on the copper foot, the thermal insulation of the outsole and the leg area above the ankle appears adequate. A deficiency exists in the toe area and either side of the major portion of the forward foot area.

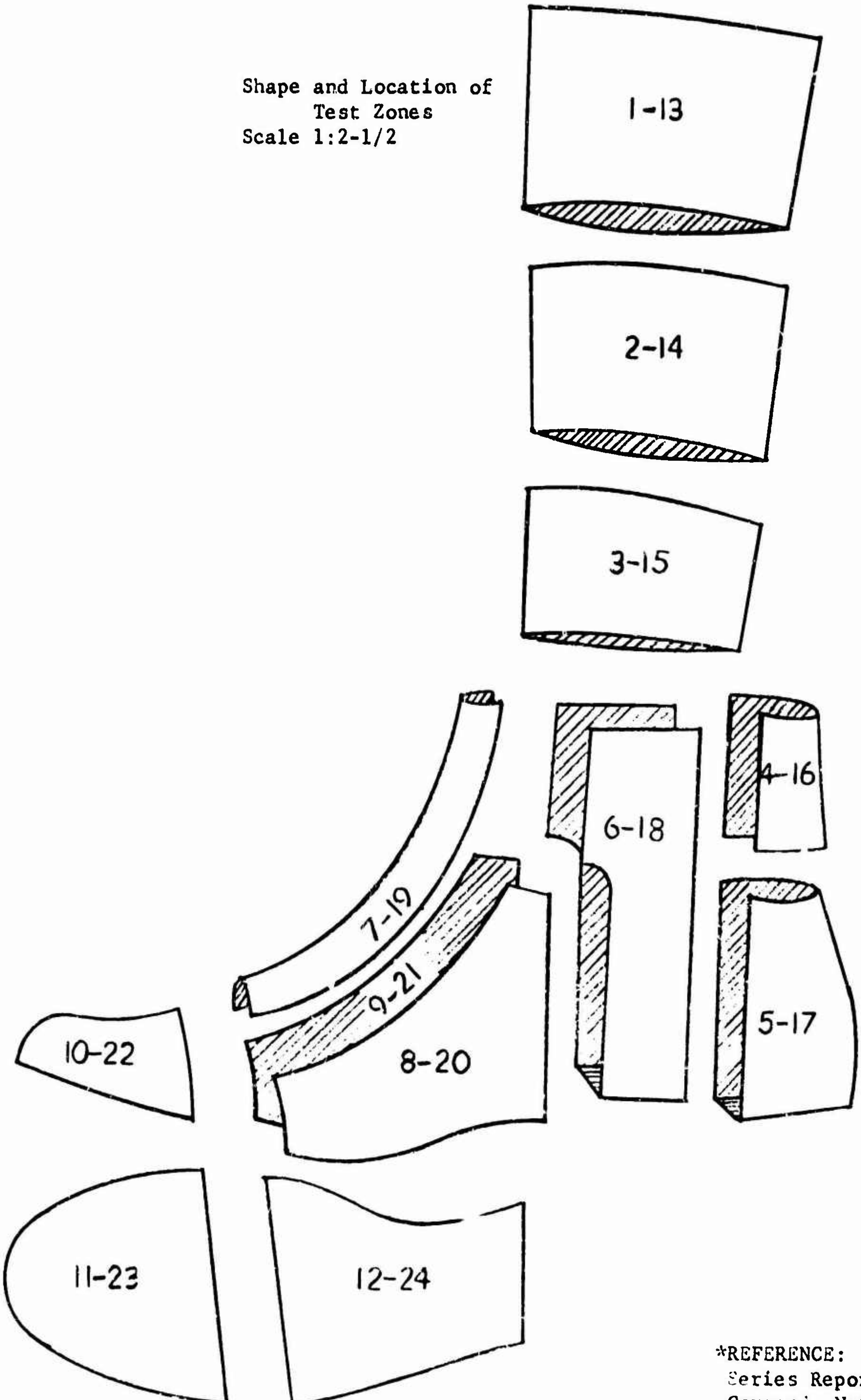
It should be noted that Boot #2 had butt seams in the upper insulation while Boot #3 seams were skived and overlapped. The Copper Foot Test did not differentiate between these two methods of construction. The Table For Copper Foot Calorimeter Data shows these results.

Based on the results obtained on Boots #2 and #3, the thickness of the upper insulation was doubled to approximately .250" on Foot #4.

Although the thickness of the polyethylene insulation in Boot #4 is approximately double that in Boot #3, the increase in clo value of Boot #4 is not considered significant. The lower clo values obtained in the sole sections of Boot #4 (sections 11-23, 12-24) resulted from the reduction in the sole thickness by approximately 1/4-inch. The thickness of the sole in Boot #3 was considered excessive and was reduced in an effort to produce better design and construction features. The lower clo value in Boot #4 over that of Boot #3 obtained in Section 3-15 which covers the ankle area is unexplainable.

COPPER FOOT TEST ZONES

Shape and Location of
Test Zones
Scale 1:2-1/2



*REFERENCE: Clothing Branch Series Report No. 16, QMR&E Command, Natick, Mass. 1960.

CONCLUSIONS

Materials research and design development have progressed sufficiently to demonstrate that the materials selected could be assembled into a boot.

Preliminary performance studies indicate that the desired thermal insulation properties for a lightweight insulated boot may be achieved. However, such features as fit, comfort during prolonged use, styling, wear, and general response to design have yet to be resolved.

SUMMARY

The work was divided into two parts: materials studies and fabrication studies. Original design concepts divided the boot into a probable minimum of nine or ten components. These were: outsoles, midsoles and/or insoles, shank supports, reinforcements for counter and toe cap, reinforcement for vamp, liner, exterior coating, adhesives, and insulation for the boot upper. Candidates of closed cell expanded (chemically blown) materials of selected densities and formulations were used for soles, counter, toe cap, and insulation. Fabrics of various weights, weaves, and chemical composition were investigated for vamp, liner, counter and toe cap. Elastomer films were tested for the exterior and metals and plastics for shank supports.

In the materials study, the candidates were prepared and altered as considered necessary and then subjected to three series of physical tests. Unsuccessful candidates were screened out in each test series. The chosen materials were as follows:

Outsoles

(1).	Expanded Polyurethane	-	Density	22-27	Lbs./Cu. Ft.
(2).	Expanded Neoprene(R)	-	"	"	"
(3).	Expanded Royalene(R)	-	"	"	"

Midsole/Insole

(1).	Expanded Polyurethane	-	Density	22-27	Lbs./Cu. Ft.
(2).	Expanded Neoprene	-	"	"	"
(3).	Expanded Royalene	-	"	"	"

Insulation

(1).	Expanded Polyethylene	-	Density	3-3.5	Lbs./Cu. Ft.
(2).	Expanded Neoprene	-	"	6-7	"
(3).	Expanded Royalene	-	"	5-6	"

Counter/Toe Cap

Expanded Rigid ABS	-	Density 10-14 Lbs./Cu. Ft.

Vamp/Liner

(1). Plain Woven Dacron(R)	-	3.3 Oz./Sq. Yd.
(2). " " Nylon	-	" " "

Exterior

(1). Polyether Polyurethane	-	About 13½ Oz./Sq. Yd.
(2). Butyl Rubber	-	" 24 " "
(3). Neoprene	-	" 25 " "

Adhesives

(1). U. S. Royal(R) Adhesive M-6230 - General Purpose

(2). " " " M-6130 - " "

(3). Bostik(R) 1225C - Polyurethane Base

Fabrication studies were made using the previously selected materials. A total of six different boot designs were investigated.

Boot #1 was made on U. S. Rubber Company Snugley Last, size 9. The liner was made from #15205 Dacron, fastened together at front and back seam with a merrow stitch. A conventional commercial inner-sole was used inside the bottom fabric lining.

A strip of 3/4" wide, .015" thick polyurethane 908 film was fastened over the front and back seam with U. S. Rubber Company M6230 adhesive. The toe cap was made with skived edges from .030" #1034A Rigid Cellular ABS.

The entire assembly was coated with adhesive, to which two pieces of skived 1/8" polyethylene #1023 insulation were attached to the full height (12") of the boot, butt seamed front and back. Strips of poly-ethylene film were placed on the seams and around the top of the in-sulation.

The outsole was plied up from slabs of cellular urethane. A 1" strip of polyurethane film was cemented around the outsole area and the entire assembly spray coated with polyurethane compound #908.

Boot #2 was made to fit the size 10 "copper foot" at Natick Laboratories.

The lining was made from two-way stretch Nylon, which proved very difficult to stitch and position on the last. The thickness of toe cap (ABS) was increased to .070".

The insulation was reduced to 9-1/2" inside height. A one-piece molded cellular polyurethane with a non-skid government tread design was used for the outsole, to which a steel shank support was attached.

Other features remained the same as Boot #1.

Boot #3 incorporated a lining made from 100% Orlon knit, which handled much better than previous linings.

Toe cap and counter were increased to 0.145" thickness.

The insulation seams were made by skiving and overlapping instead of butt seaming. Reinforcing strips were not required on the insulation seams.

U. S. Rubber Company #M6130 cement was used in place of M6230.

Other details remained the same. Boot #3 was much improved over #1 and #2, although tests showed it to be deficient in insulating qualities in certain areas.

Boot #4 was similar to Boot #3 except that lining was coated both sides with a urethane solution. Other changes were an increase in gauge of the insulation to 1/4", and a reduction in outsole thickness and weight.

Other features remained the same.

Boot #5 essentially was equivalent to Boot #4, except that an Orlon liner was coated with polyurethane solution on the outside only for determination of thermal insulating properties, as requested by the Project Officer. The total weight of this boot was 15-1/2 oz., and represented the best results of experience gained from the other designs. This boot was worn by the Project Officer during an actual human evaluation test in the climatic chambers at Natick. The result of this test demonstrated that the materials selected essentially satisfied functional objectives of a lightweight insulated waterproof boot (See Appendix A).

Design development has progressed sufficiently to demonstrate that the materials selected could be assembled into a boot. However, such features as fit, comfort during prolonged use, styling, wear, and general response to design have yet to be resolved.

Boot #6 was the last one to be designed during this study. The principle feature of this boot was the use of two layers of 1/8" insulation instead of one layer on 1/4" insulation. The two layers were adhered together at the top and bottom only, to allow for greater flexibility.

The other change was the use of a polypropylene fabric lining for easier donning and doffing.

ACKNOWLEDGEMENTS
(U. S. Rubber Co.)

The authors wish to acknowledge the assistance of Algis Brazdzionis, P. E. Sitler and J. T. Parker for their work on polyurethane outsoles and coatings.

The guidance of J. F. Summa in development of design concepts is appreciated.

The efforts of J. T. Gleissner and L. A. Ferguson in preparation of the cellular insulation are gratefully acknowledged.

LITERATURE SURVEY AND BIBLIOGRAPHY

The bibliography lists the literary materials used for this work. USRC (United States Rubber Company) "Company Private" literature was the best source of information. This was true because advances of the art give economic advantages to the originating company and are therefore not published. Raw material suppliers' literature is reasonably current with the state of the art and was therefore useful. Other published information was valuable for establishing general properties of materials.

The general technique used in the search was to use other literature as a guide in searching USRC literature. Formulas were used as they were found as nearly as possible. This was due to the very critical balance of properties in closed cell sponge, particularly those of cure and blow. This accounts for formulas having fire retardants and the like.

1. EPDM Royalene

   "United States Rubber Company (hereafter designated USRC) Royalene Technical Committee" data. Reports used were those from (1) June 22, 1964 meeting at Naugatuck, Conn., (2) February 16, 1965 meeting at Baton Rouge, Louisiana, (3) June 29, 1965 meeting at Philadelphia, Pennsylvania, (4) December 2, 1965 meeting at Wayne, New Jersey, and (5) May 9, 1966 meeting at Detroit, Michigan.

2. CR, Neoprene

   a. "The Neoprenes" by Murray and Thompson - duPont, March, 1963.

   b. USRC Report 60-L-7297-2942 by GOC - Laboratory, (Company Private), Mishawaka, Indiana, 1960.

   c. USRC Report 60-F6-41 by W. W. Neill (Company Private), Mishawaka, Indiana, 1960.

   d. Various other USRC "Company Private" reports, letters, etc.

3. IIR, Butyl

   a. Enjay's "Butyl Compounding Handbook", New York, 1963.

   b. USRC Report 58-F6-16 by R. W. Pooley, Mishawaka, Indiana, 1958.

   c. " " 59-F6-32 by W. W. Neill, " " 1959.

d. USRC Report 56-F6-5 by R. W. Pooley, Mishawaka, Indiana, 1956.

e. " " 56-F6-11 by R. W. Pooley, " " 1956.

4. CSM, Hypalon

a. DuPont's "Hypalon Report" Nos. 2 (December, 1960), 3 (December, 1960), 4 (December, 1960), and 7 (May, 1961), Wilmington, Delaware.

b. DuPont's Elastomers Division Reports BL-311, BL-313, and BL-332, No Dates, Wilmington, Delaware.

c. DuPont's Elastomer Chemicals Dept. Bulletins PB-8 (December, 1959) and PB-11 (May, 1960), Wilmington, Delaware.

d. DuPont's "Hypalon 40" Report No. 59-2, June, 1959, Wilmington, Delaware.

e. DuPont's "Coatings of Hypalon 20 Synthetic Rubber" Report No. 56-10, November, 1956, Wilmington, Delaware.

f. USRC Report 60-F1-31 by W. W. Neill (Company Private), Mishawaka, Indiana, 1960.

g. USRC Report 60-F1-33 by W. W. Neill (Company Private), Mishawaka, Indiana, 1960.

h. USRC Report 61-F6-42 by W. W. Neill (Company Private), Mishawaka, Indiana, 1961.

i. Various USRC "Company Private" reports, letters, etc.

5. PVC/NBR, Polyvinyl Chloride/Acrylonitrile (Marvinol/Paracril)

a. Various USRC "Company Private" letters, reports, production formulas, etc.

b. USRC "Company Private" Ensolite Manufacturing Specifications.

6. Polyurethane

a. "Adiprene" Urethane Rubber Bulletins issued by Elastomer Chemicals Dept., E. I. duPont de Nemours and Co., (Inc.), Wilmington, Delaware.

b. "Vibrathane" Urethane Literature issued by Chemical Division of USRC, Naugatuck, Conn.

7. Polyethylene

   a. USRC Report 56-F6-25 by G. L. Barnes (Company Private), Mishawaka, Indiana, 1958.

   b. Various other USRC "Company Private" reports, letters, patent application, etc.

   c. "Modern Plastics Encyclopedia", 1965 Edition.

   d. Various U.S.I. Polyethylene Technical Bulletins.

8. ABS, Acrylonitrile Butadiene Styrene

   a. USRC Report 62-Q5-49 by R. W. Pooley (Company Private), Mishawaka, Indiana, 1962.

   b. USRC Report 63-Q5-55 by R. W. Pooley (Company Private), Mishawaka, Indiana, 1963.

   c. USRC Naugatuck Chemical Division's Kralastic ABS Resins Technical Bulletins - 1963, 1964, 1965.

   d. Various USRC "Company Private" reports, letters, production formulas, etc.

9. Acetal, Nylon, Polycarbonate

   a. "Modern Plastics Encyclopedia", 1965 Edition.

   b. Various Property Comparison Charts from various plastic suppliers.

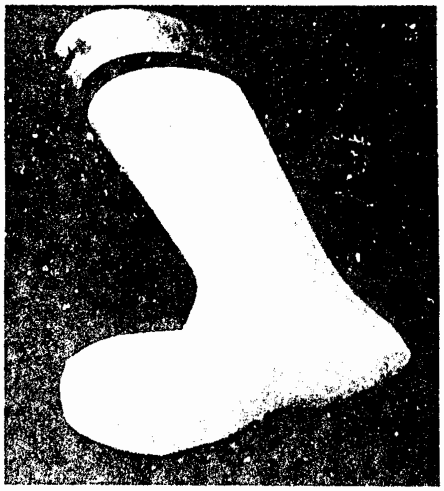
10. Fabrics

    Wellington-Sears "Handbook of Industrial Textiles".

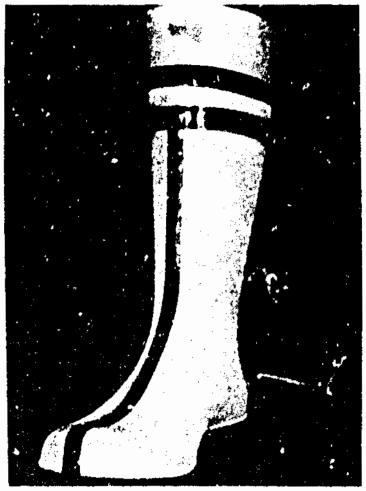
11. IM, Vistanex

    Various Enjay Technical Bulletins on Vistanex.

PROTOTYPE LIGHTWEIGHT INSULATED BOOT IN VARIOUS STAGES OF FABRICATION



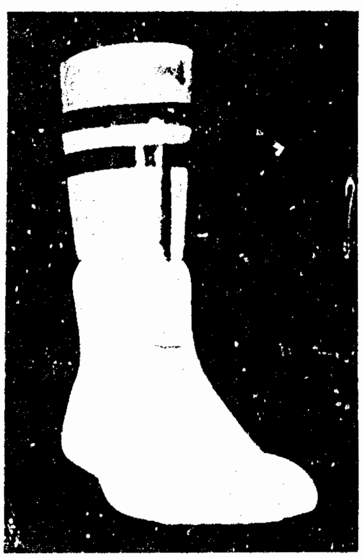
1 - Leg and sock lining wrap around strip.



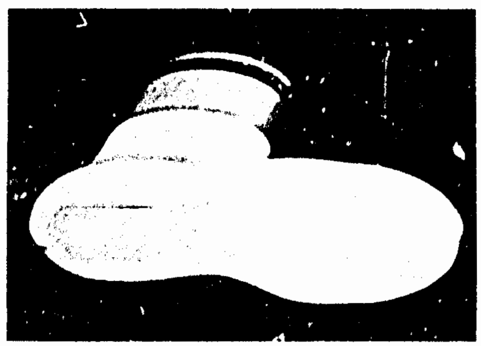
2 - Seam sealing strip top band.

3 - Toe cap and counter.

4 - Left side insulation. Note cemented skive.



5 - Completed leg insulation.

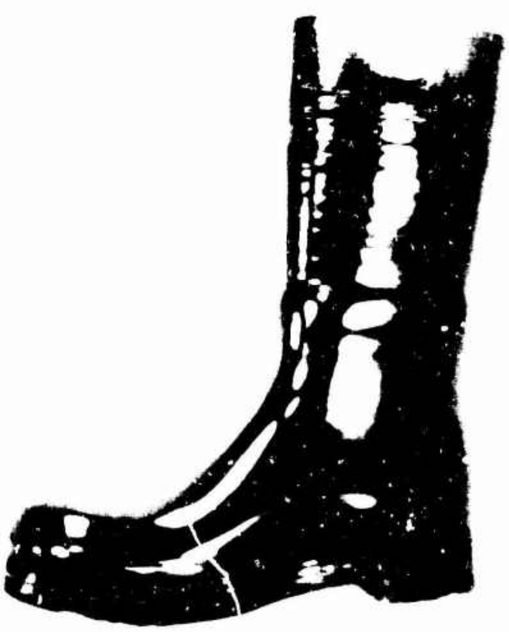


6 - Leg insulation extension on bottom.

PROTOTYPE LIGHTWEIGHT INSULATED BOOT
IN VARIOUS STAGES OF FABRICATION

7 - Outsole.

8 - Outsole with foxing.



9 - Sprayed boot with last covering.

10 - Complete boot.

APPENDIX A

AMXRE-CRP 20 June 1966

I. LABORATORY REPORT CF#19 U. S. ARMY NATICK LABORATORIES

TITLE: Preliminary Climatic Chamber Evaluation of Experimental Lightweight Insulated Boot Materials.

BY: JOSEPH E. ASSAF

Background

Under Project title, "Individual Combat Protection Clothing and Equipment, Exploratory Development", materials research studies are being conducted to develop new lightweight materials to be used as components or groups of components in fabricating lightweight insulated footwear.

There are presently two standard insulated boots in the system. They are described as follows:

1. Boot, Insulated, Cold Weather, Rubber (Black) for Wet Cold Use. These boots have been designed to protect feet where the mean monthly temperatures range between 14° F. and 68° F. The boot should not be worn when temperatures fall below -20°F.

2. Boot, Insulated, Cold Weather, Rubber (White) for Cold Dry Use. These boots have been designed to protect under sub-zero conditions and should be worn when ambient temperatures of -20° F. or below may occur.

Concurrent with the study reported herein, properties other than insulation are being investigated. The results will be the subject of future reports.

Test Procedure

Based upon data obtained to date from materials research studies being conducted with U. S. Rubber Company under Contract No. DA19-129-AMC-690(N), candidate materials in a general boot form were assembled by means of basic fabrication techniques and a pull-on type design. This experimental boot was used to determine the insulating properties of the materials in combination with each other. The finished assembly of these experimental materials weighed 15.5 ounces as shown in Figure 1.

Figure 1. Assembly of materials in general boot form

The only "standard" boot available at the time of test had a 1/4-inch felt (instead of the 3/8-inch of the regular standard) for the insoles and 11.5-ounce fleece (instead of the 19-ounce for the regular standard) for the upper insulation. This boot weighed 38-ounces.

The author, acting as test subject wore the 15.5-ounce experimental boot on the right foot and the black 38-ounce standard insulated boot on the left boot for two hours in the NLABS climatic research test chamber at -30° F. In order to study the insulating properties of the materials and determine the feasibility of providing lighter weight insulated boots without significantly decreasing the effectiveness of the insulating value over that of the current standard black insulated boot, thermocouples were attached to each foot as follows:

1. Big Toe
2. Little Toe
3. Instep
4. Ankle

Figure 2 illustrates the location of each thermocouple.

A single standard cushion-sole wool sock was worn on each foot and the uniform was that for standard cold weather Army use.

Evaluation of Climatic Chamber Test Data

Figures 3, 4, 5, and 6 present a comparison of the rate of change in temperature of the various parts of the foot in the control and experimental boot over the two-hour period at -30°F.

Under the conditions of this limited study, the data show that, when new, the experimental boot is equal in insulating properties to the standard test boot.

Figure 3 compares the temperature change in the little toe area. The data show that the standard boot exhibits slightly better insulating properties in this area. However, the results towards the end of the two-hour test period indicate that the two boots can be considered equivalent in insulating properties.

The twenty-six minute period (between the 40 and 66 minute periods in the test) of complete inactivity (sitting) is illustrated on all of the graphs. It shows a more rapid drop in temperature than the periods of minimum activity (slow walking) also illustrated. The period of inactivity affects the slope of the curves. It should be noted that, upon resuming minimum activity (walking), the curves begin to level off.

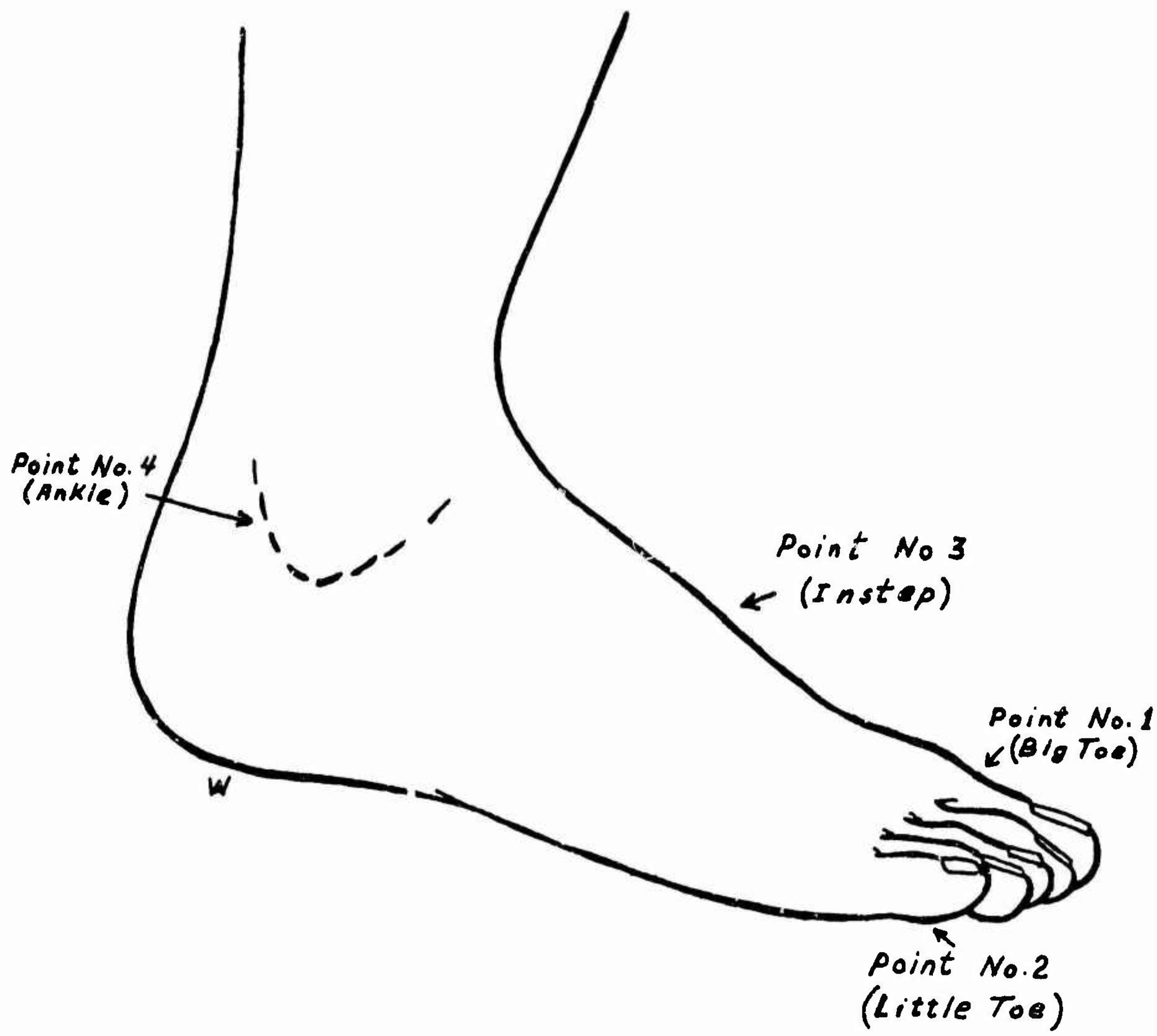


Figure 2. Thermocouple location points

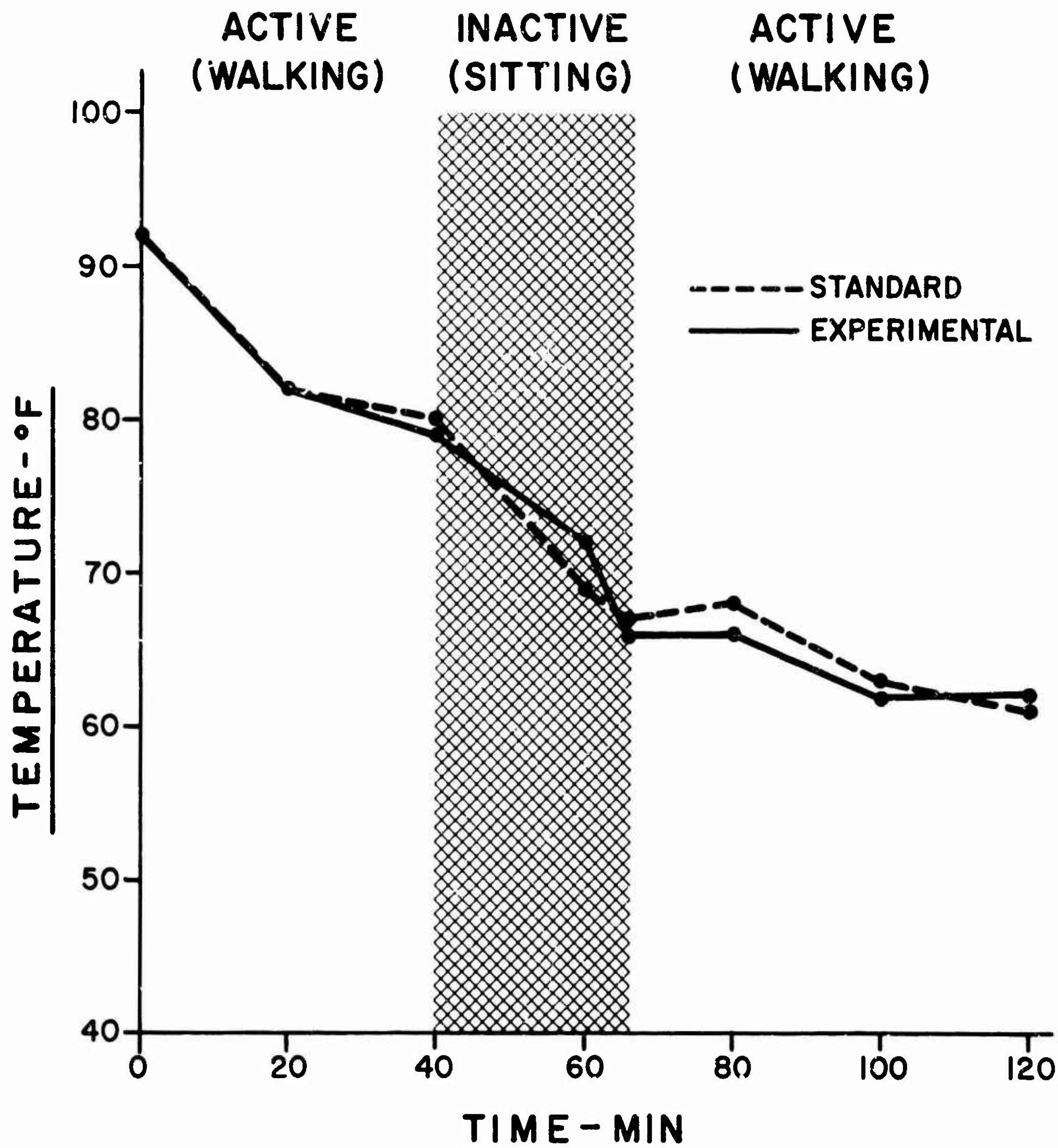


Figure 3. Comparison of Standard and Experimental Insulated Boots
Test temperature -30° F
Thermocouple #1 (big toe)

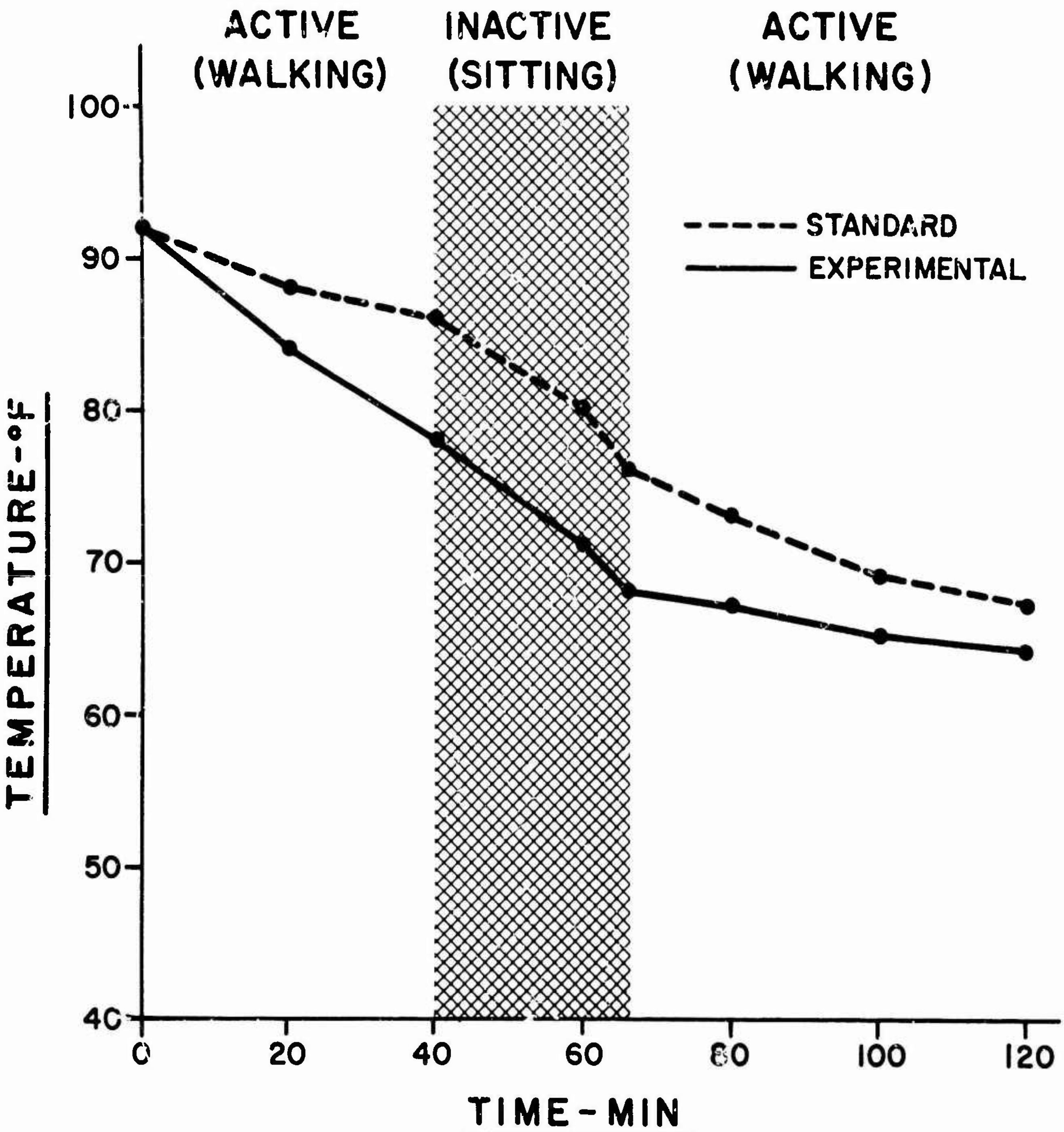


Figure 4. Comparison of Standard and Experimental Insulated Boots
Test temperature -30° F
Thermocouple #2 (little toe)

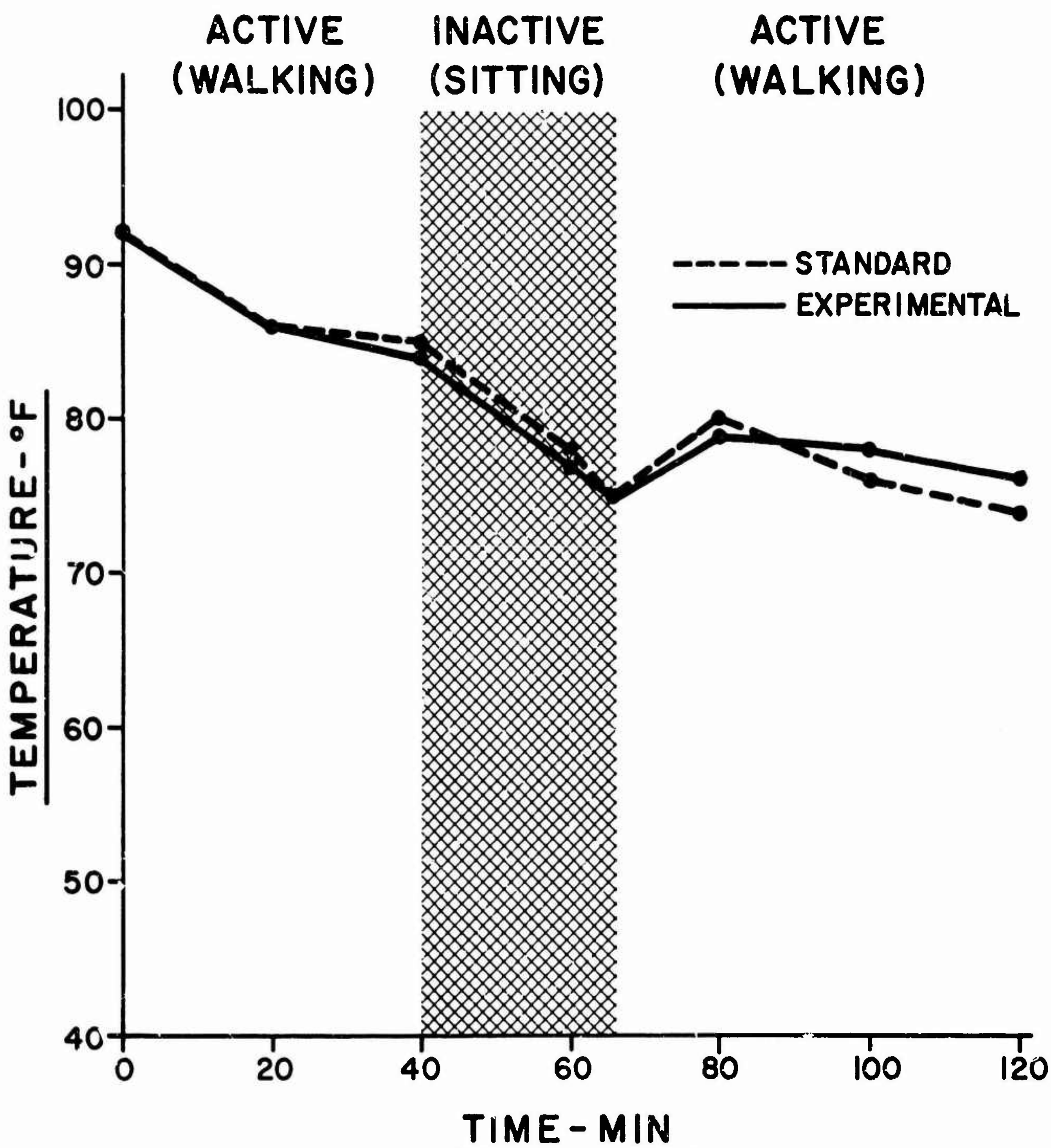


Figure 5. Comparison of Standard and Experimental Insulated Boots
Test temperature -30° F
Thermocouple #3 (instep)

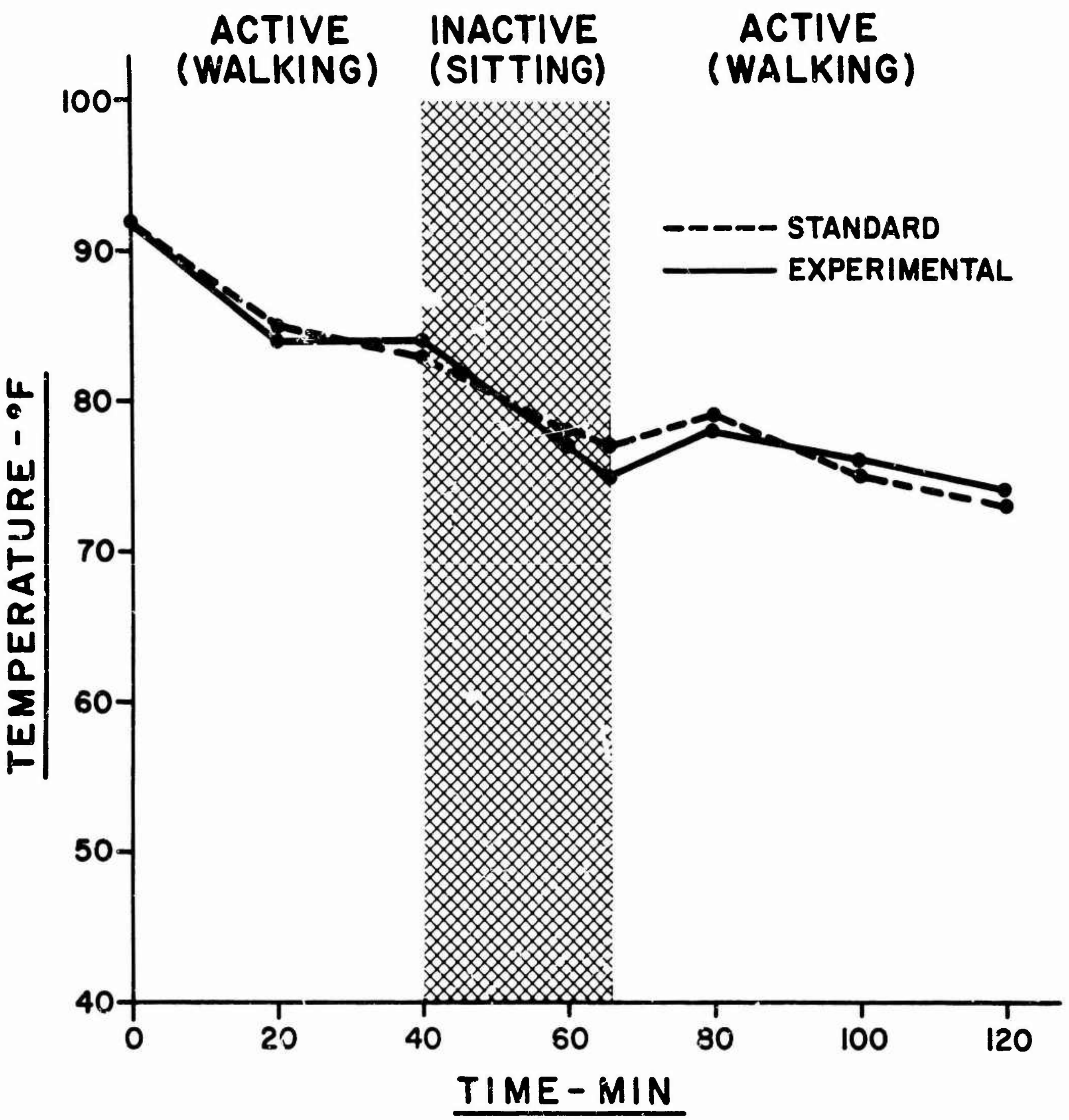


Figure 6. Comparison of Standard and Experimental Insulate
Test temperature -30° F
Thermocouple #4 (ankle)

The 92° F. initial temperature reading shown on all of these figures was caused by the excessive heat build-up during the donning of the boots and the arctic clothing. The rapid initial drop recorded in the first twenty-minutes is not considered significant since this time can be considered as the time required for the clothing ensemble to come to equilibrium.

Table I shows the significant time-temperature relationship between the two boots.

Table I

Time-Temperature Relationship

	Standard Boot			Experimental Boot		
	20 Min.	66 Min.	120 Min.	20 Min.	66 Min.	120 Min.
Big Toe	82° F.	67° F.	61° F.	82° F.	66° F.	62° F.
Little Toe	88° F.	76° F.	67° F.	84° F.	68° F.	64° F.
Instep	86° F.	75° F.	74° F.	86° F.	75° F.	76° F.
Ankle	83° F.	77° F.	73° F.	84° F.	75° F.	74° F.

The following was noted during the test:

1. Upon flexing the experimental boot in the toe area, a sharp crease was noted. There were no serious effects and the crease began to disappear slowly when the boot was not flexed.

2. Visual examination of the experimental boot at the completion of the test showed no breaks or cracks in the boot materials.

Conclusion

At the temperatures encountered during this limited test, there was no noticeable difference in low temperature foot comfort between the standard and experimental boot.

The results indicate that the experimental materials, assembled in the form of a boot which weighs only 15.5-ounces, give adequate insulative protection and probably exceed the requirement of providing protection down to -20°F. for periods of two hours of inactivity.

APPENDIX A (Cont'd.)

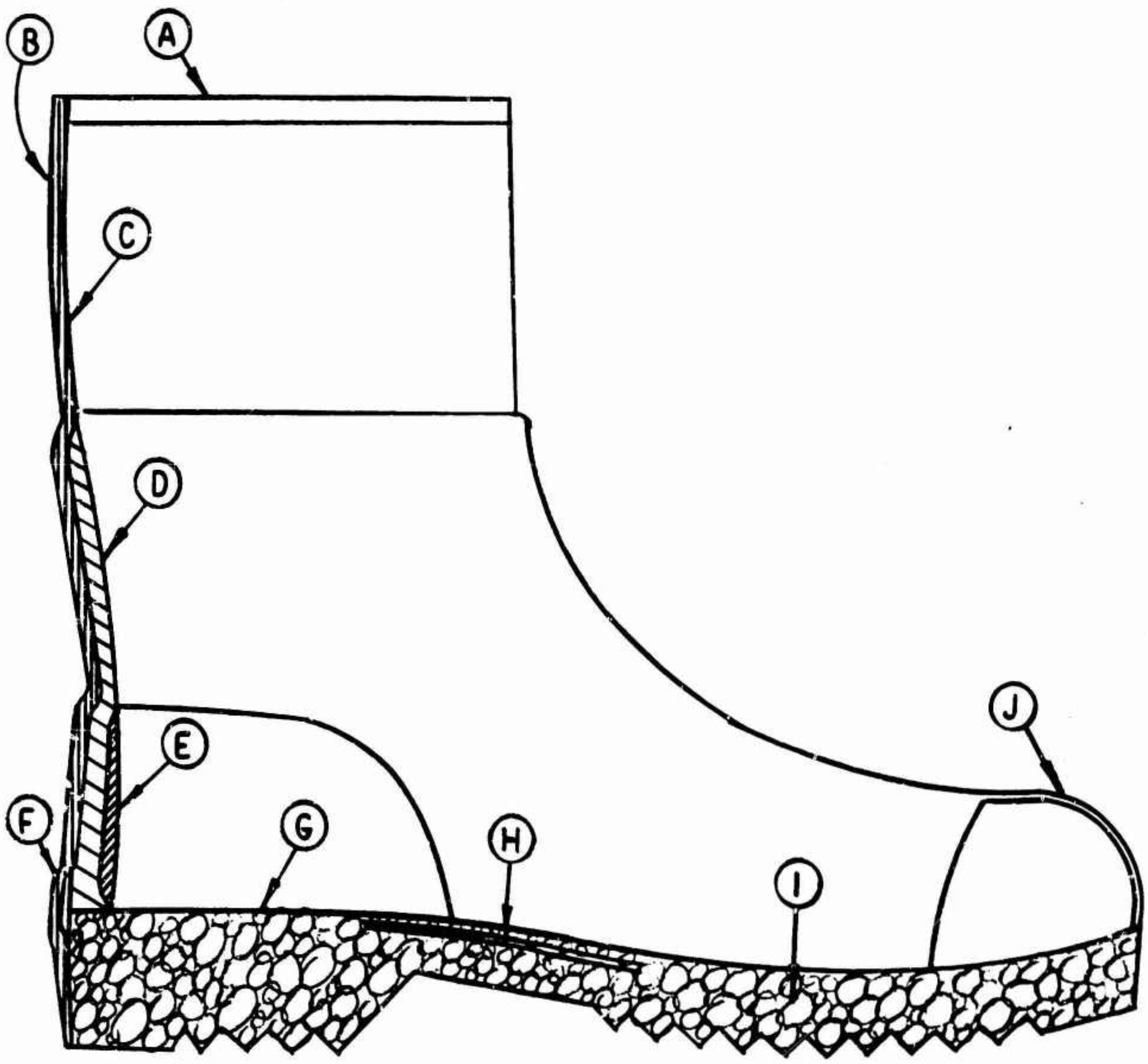
(Supplement to Laboratory Report CF #19, Preliminary Climatic Chamber Evaluation of Experimental Lightweight Insulated Boot Materials, by Joseph A. Assaf)

Description of Experimental Lightweight Materials Assembled in Boot Form

Nomenclature	Material	Density Lbs./Cu. Ft.	Thickness Inches
Lining Fabric	100% Orlon	--	--
Upper Insulation	Closed Cell Polyethylene	3.0 - 3.5	0.253
Toe Cap & Counter	Rigid, Cellulars Acrylonitrile/ Butadiene/Styrene (ABS)	13.0	0.145
Insole-Midsole-Outsole	Closed Cell Polyurethane	25 - 27	0.725
Reinforcement Strips	Polyurethane	--	
Shank Support	Stainless Steel	--	
Adhesive	Neoprene Base	--	

APPENDIX-B
INITIAL DESIGN CONCEPT

LIGHTWEIGHT INSULATED BOOT



LEGEND

A - TOP BAND
B - EXTERIOR COATING
C - FABRIC LINING
D - LEG INSULATION
E - COUNTER
F - FOXING STRIP
G - FABRIC SOCK LINING
H - SHANK
I - INTEGRALLY MOLDED CELLULAR MIDSOLE-OUTSOLE-HEEL
J - TOE CAP

APPENDIX—C

PATTERNS

LIGHTWEIGHT INSULATED FOOTWEAR

CONTRACT NO. DA 19-129-AMC-690(N)

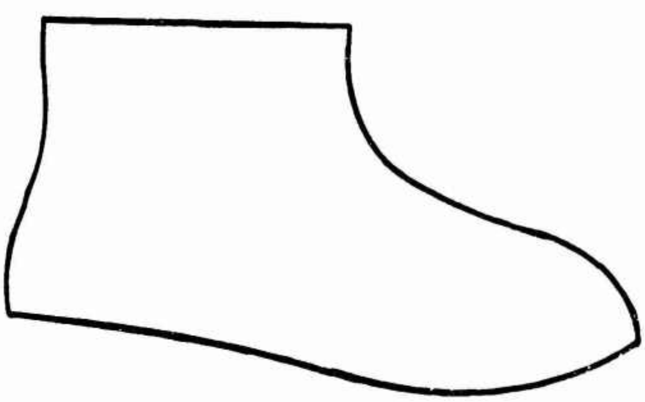
SCALE—1/4 SIZE

LINING

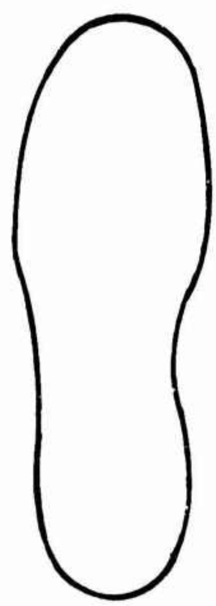
SOCK LINING

INSIDE COUNTER

INSIDE TOE CAP



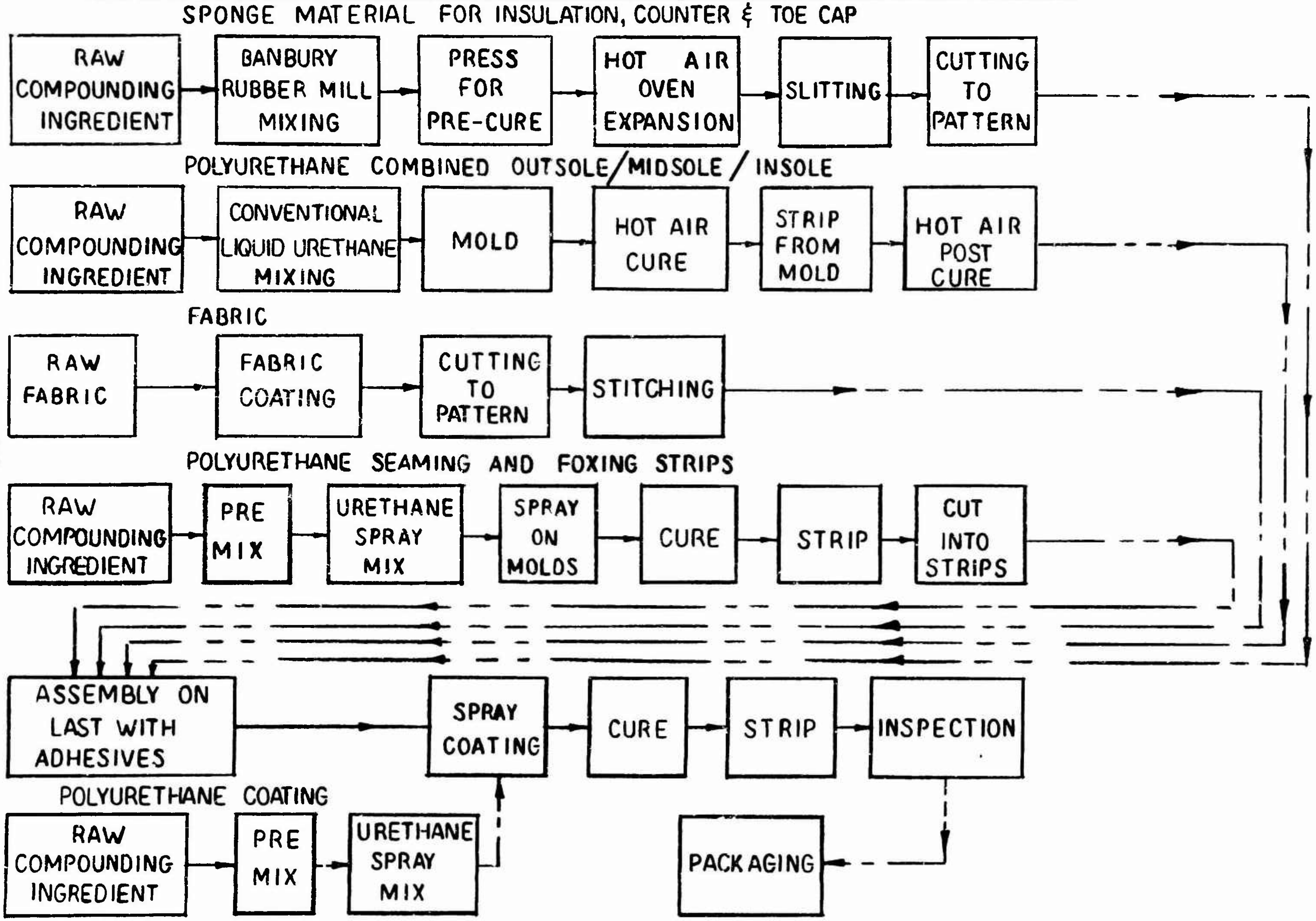
INSULATION



COMBINED
OUTSOLE / MIDSOLE / INSOLE

APPENDIX—D

FLOW SHEET—LIGHTWEIGHT INSULATED FOOTWEAR—CONTRACT NO. DA19-129-AMC-690(N)



APPENDIX E

Description of Fabrics and Suppliers

1. USRC Mishawaka Plant Stock Items

   a. 3.5011 Plain Woven Glass Style 162/150

   b. 3.5310 Plain Woven Nylon A-3643 3.3 oz./sq. yd.

   c. 3.5326 Plain Woven Nylon 5.6 oz./sq. yd.

   d. 3.5336 Knit Nylon S/7024L 2.3 oz./sq. yd.

   e. 3.5343 Plain Woven Nylon A-2679 2.0 oz./sq. yd.

   f. 3.5376 Plain Woven Nylon Putnam Style 34231 5.1 oz./sq. yd.

   g. 3.5440 Plain Woven Dacron S & S Style 15023 4.5 oz./sq. yd.

2. Wellington Sears Company

   a. EXP FV1587 Plain Woven Dacron 7.1 oz./sq. yd.

   b. FV2994 Plain Woven Dacron 7.5 oz./sq. yd.

   c. 3-9027-1 Nonwoven Lantuck 9.0 oz./sq. yd.

   d. S/3582 Plain Woven Dacron 2.4 oz./sq. yd.

   e. S/FV3796 Plain Woven 3.3 oz./sq. yd.

   f. S/3465 Plain Woven Nylon 2.0 oz./sq. yd.

   g. S/3529 Plain Woven Nylon 1.8 oz./sq. yd.

   h. S/3458 Plain Woven Dacron 1.2 oz./sq. yd.

   i. S/3471 Plain Woven Dacron 1.7 oz./sq. yd.

   j. 3584 Plain Woven Dacron 1.8 oz./sq. yd.

3. <u>Chicoppe Mills, Inc.</u>

   a. SAN 3500-RC1131 Nonwoven Nylon 8.0 oz./sq. yd.

   b. SAN 3500-RC1252 Nonwoven Dacron 8.0 oz./sq. yd.

4. <u>Famco, Inc.</u>

   SP803 Nonwoven Glass Hi Density 1 oz./sq. ft.

5. <u>Lawrence Mfg. Co., Division of Ames Textile Corp.</u>

   R-5048 Knit Nylon 5.1 oz./sq. yd.

6. <u>Pilot Fabrics, Inc.</u>

   a. 6440 Knit Dacron 3.7 oz./sq. yd.

   b. 6540 Knit Dacron 5.0 oz./sq. yd.

7. <u>Stern & Stern Textiles, Inc.</u>

   a. 15035 Plain Woven Dacron 4.5 oz./sq. yd.

   b. 15302 Plain Woven Dacron 1.4 oz./sq. yd.

   c. 15205 Plain Woven Dacron 3.3 oz./sq. yd.

8. <u>Frank Ix & Sons</u>

   S/9029 Twill Woven Nylon 1.5 oz./sq. yd.

9. <u>Putnam Mills Corp.</u>

   P9483 Twill Woven Nylon 3.0 oz./sq. yd.

10. <u>Burlington Industries, Inc.</u>

    a. 81450 Plain Woven Dacron 4.4 oz./sq. yd.

    b. 81719 Plain Woven Dacron 4.3 oz./sq. yd.

11. <u>Wm. Heller, Inc.</u>

    Heiress Style Knit Orlon 4.6 oz./sq. yd.

APPENDIX F

Registered Trademarked Items

1.	Adiprene(R)	-	E. I. duPont de Nemours & Company (Inc.)
2.	Alathon(R)	-	" " " " "
3.	Bismate(R)	-	R. T. Vanderbilt Company
4.	Bostik(R)	-	B. B. Chemical Company, a Division of United Shoe Machinery Corporation
5.	Celogen(R)	-	United States Rubber Company
6.	Dabco(R)	-	Houdry Process & Chemical Company
7.	Dacron(R)	-	E. I. duPont de Nemours & Company (Inc.)
8.	Delrin(R)	-	" " " " "
9.	Di-Cup(R)	-	Hercules Powder Company
10.	Ensolite(R)	-	United States Rubber Company
11.	Ferro(R)	-	Ferro Corporation
12.	Flexol(R)	-	Carbide & Carbon Chemicals Company
13.	Hycar(R)	-	B. F. Goodrich Chemical Company
14.	Hypalon(R)	-	E. I. duPont de Nemours & Company, (Inc.)
15.	Kenflex(R)	-	Kenrich Corporation
16.	Kralastic(R)	-	United States Rubber Company
17.	Lexan(R)	-	General Electric
18.	Marvinol(R)	-	United States Rubber Company
19.	Monex(R)	-	United States Rubber Company
20.	Monoplex(R)	-	Rohm & Haas Company
21.	Neophax(R)	-	Stamford Rubber Supply Company

22.	Neozone(R)	-	E. I. duPont de Nemours & Company (Inc.)
23.	Nitrosan(R)	-	" " " " "
24.	OXAF(R)	-	United States Rubber Company
25.	Paracril(R)	-	" " " "
26.	Permalux(R)	-	E. I. duPont de Nemours & Company (Inc.)
27.	Plastolein(R)	-	Emery Industries, Inc.
28.	Pliolite(R)	-	Goodyear Tire & Rubber Company
29.	Polycin(R)	-	Baker Castor Oil Company
30.	Polygard(R)	-	United States Rubber Company
31.	Royalene(R)	-	" " " "
32.	Royalex(R)	-	" " " "
33.	Silene(R)	-	Columbia-Southern Chemical Corporation
34.	Staybelite(R)	-	Hercules Powder Company
35.	Sulfasan(R)	-	Monsanto Chemical Company
36.	Sundex(R)	-	Sun Oil Company
37.	Suprex(R)	-	National Carbon Company
38.	Tellurac(R)	-	R. T. Vanderbilt Company
39.	Tetrone(R)	-	E. I. duPont de Nemours & Company (Inc.)
40.	Thermolastic(R)	-	Shell Chemical Company
41.	Thionex(R)	-	E. I. duPont de Nemours & Company (Inc.)
42.	TiPure(R)	-	" " " " "
43.	U. S. Royal(R)	-	United States Rubber Company
44.	Vibrathane(R)	-	" " " "
45.	Vinylite(R)	-	Carbide & Carbon Chemicals Company
46.	Vistanex(R)	-	Enjay Company
47.	Vultac(R)	-	Sharples Chemicals, Inc.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

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Final Report

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13. ABSTRACT

In this study, a number of candidate materials were compounded, tested, and evaluated with an aim toward the development of a lightweight (15 oz. per boot), impermeable, (water absorption maximum weight 5%), insulated, (for service down to -20°) boot for periods up to 2 hours of inactivity.

These materials included expanded elastomers and plastics, solid plastics, metals, fabrics, adhesives, and coating materials.

Design and fabrication studies were conducted to incorporate the most promising materials into a prototype boot, and to determine the insulating properties of the materials used singly and in combination with each other.

Based on the data obtained, prototype boots were assembled. An experimental pull-on type boot weighing 15½ ounces was worn by the Project Officer in the Climatic Test Chambers at the U. S. Army Natick Laboratories at -30°F. for a period of 2 hours.

These studies indicate the feasibility of producing lightweight insulated boots through materials research.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Evaluation	8					
Elastomers	9					
Plastics	9					
Fabrics	9					
Adhesives	9					
Coatings	9					
Boots	4		9			
Lightweight	0		0			
Insulated	0		0			
Impermeable	0		0			
Armed Forces Supplies	4		4			
Design			8			
Fabrication			8			

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